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Ground Water Investigation and Remediation

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Introduction

During 1998, ground water investigations and remediations under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) continued at both the Livermore site and Site 300. LLNL regularly samples and analyzes ground water from areas of known or suspected contamination. Portions of the two sites that contain ground water with concentrations of chemicals of concern are actively investigated to determine the magnitude of the contamination and its source. Remediation strategies are developed and evaluated in preparation for a CERCLA removal action or through the feasibility study process. An approved remedy for each study area is developed in consultation with the regulatory agencies and the community. This chapter reviews the distribution of contaminants in ground water, and the progress LLNL has made in removing contaminants from ground water and from the unsaturated zones (soil vapor) at the Livermore site and Site 300.

Livermore Site Ground Water Project

Physiographic Setting

The general topography of the Livermore site is described in Chapter 1. The Livermore Valley ground water system is a sequence of semiconfined aquifers in which ground water moves downslope from the valley uplands toward the east-west axis of the valley. It then flows generally westward toward the southwest portion of the basin. From there, ground water has historically flowed south into the Sunol Valley Ground Water Basin. The largest quantities of ground water are pumped from the central and western portions of the Livermore Valley, where the valley fill is thickest.

The valley fill sediments make up two aquifers: the Livermore Formation and its overlying alluvium. The Livermore Formation averages about 1000 m in thickness and occupies an area of approximately 250 km^2. The alluvium, which is about 100-m thick, is the principal water-producing formation within the valley.

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Hydrogeology

Sediment types at the Livermore site are grouped into four categories—clay, silt, sand, and gravel—based on dominant particle size. Ground water flow beneath the site is primarily in alluvial sand and gravel lenses and channels, bounded by the less permeable clays and silts. The alluvial sediments have been mapped into seven hydrostratigraphic units (HSUs) beneath the Livermore site using data collected over the years. HSUs can be defined as sedimentary sequences whose permeable layers show evidence of hydraulic connection. The HSUs of concern beneath the Livermore site are the Quaternary alluvial deposits of the upper Livermore member of the Livermore Formation (see **Figure 8-1)**. HSUs 1B, 2, 3A, 3B, 4 and 5 contain contaminants, which are primarily solvents (Blake et al. 1995 and Hoffman et al. 1998).

Remedial Activities

In 1998, the Livermore site Ground Water Project (GWP) treated almost 1000 ML of ground water, brought new treatment facilities on line, installed wells, conducted hydraulic tests, developed ground water models, published required documents, and maintained close contact with regulatory agencies and the community.

LLNL operated ground water treatment facilities and vapor treatment facilities (VTF) in the TFA, TFB, TFC, TFD, TFE, TFG, TF406, TF518, and TF5475 areas. A total of 60 ground water extraction wells operated at 16 separate locations at an average flow rate of 2.7 ML / day in 1998. VTF518 operated at an average vapor flow of 2000 m^3 / day. **Table 8-1** shows the volumes of ground water and soil vapor treated at the facilities and the estimated volatile organic compound (VOC) mass removed from the subsurface during 1998 and since the beginning of the remediation. A graph of VOC mass removal at the Livermore site since 1989 is presented in **Figure 8-2**. Concentrations of remaining VOCs in the fourth quarter of 1998 are depicted as concentration isopleths in the five HSUs in **Figures 8-3** to **8-7**.

Table 8-2 lists the extraction wells according to the hydrostratigraphic unit in which they are screened and the total flow rate for each treatment area. Together, these treatment facilities removed approximately 150 kg of VOC mass in 1998. Since operations began, approximately 3000 ML of ground water and almost 0.21 million m^3 of vapor have been treated, and more than 483 kg of VOCs have been removed. The VOC plumes in HSUs 1B, 2, 3A, 4 and 5 continue to be hydraulically controlled based on trends in ground water chemistry, capture zone analysis, and the total VOC isoconcentration maps (**Figures 8-3–7**) for each HSU.

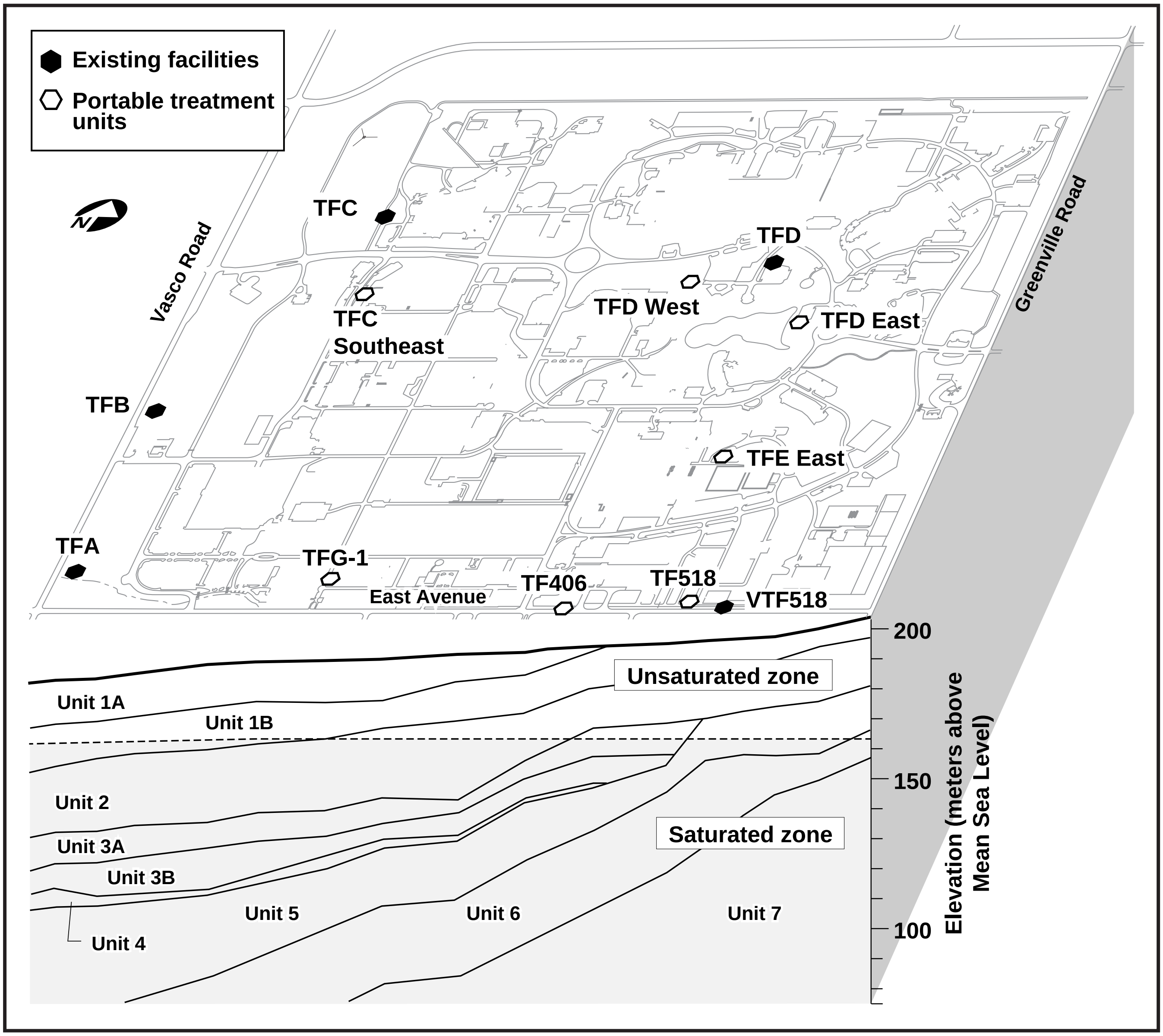


Figure 8-1. Map and cross section of the Livermore site showing hydrostratigraphic units and the locations of the treatment plants.

The numbers and locations of new wells installed in 1998 are shown in **Table 8-3**. Well construction details, well closure data, and results of drawdown tests are provided in the *LLNL Ground Water Project 1998 Annual Report* (Aarons et al. 1998).

Table 8-1. Volatile organic compounds (VOCs) removed from ground water and soil at the Livermore site.

Treatment facility[a]	Startup date	1998		Cumulative total	
		Water treated (ML)[b]	VOCs removed (kg)	Water treated (ML)[b]	VOCs removed (kg)
TFA	9/89	469	15	1950	109
TFB	10/90	68	5.2	316	31
TFC	10/93	87	7.9	223	23
TFD	9/94	238	73	470	147
TFE	11/96	53	17	93	34
TFG1	4/96	11	0.4	27	1.2
TF406	8/96	45	2.1	56	1.2
TF518	1/98	11	1.0	11	1.0
TF5475	9/97[c]	0.12	0.4	0.14	0.5
Total		982	121	3146	349
		Soil vapor treated (m^3)	VOCs removed (kg)	Soil vapor treated (m^3)	VOCs removed (kg)
VTF518[d]	9/95	141,000	27.3	316,000	134

a Includes fixed and portable units.

b ML = 1 million liters.

c Activation date.

d Volatile extraction well.

Treatment Facility A

Treatment Facility A (TFA) is a fixed facility that is located in the southwestern quadrant of the Livermore site near Vasco Road and East Avenue (**Figure 8-1**). Ground water is treated using the large-capacity air-stripping system that was installed in June 1997. The VOCs are stripped from the ground water, and the effluent air from the stripper is passed through granular activated carbon (GAC) filters to remove the VOCs. The treated effluent air is then vented to the atmosphere. The California Regional Water Quality Control Board (RWQCB) permits LLNL to treat up to 500 gallons per minute (gpm) of ground water. Treated ground water from TFA is discharged to the Recharge Basin, located about 600 m southeast of TFA on Department of Energy (DOE) property administered by Sandia National Laboratories / California. Since startup of the new system, TFA has not exceeded the 5 parts per billion (ppb) total VOC discharge limit. Two wells were installed in the TFA area in 1998 (see **Table 8-3**). Three other boreholes were drilled for infiltration studies.

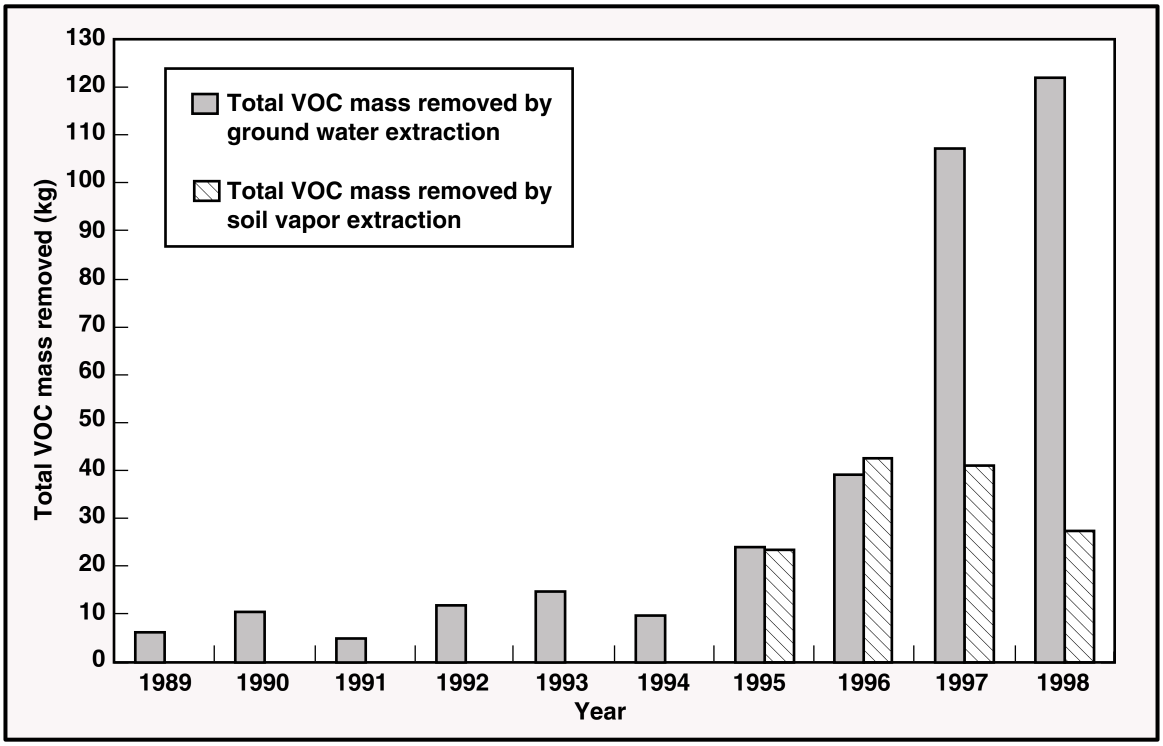


Figure 8-2. Total VOC mass removed from the subsurface of the Livermore site between 1989 and 1998.

Treatment Facility B

Treatment Facility B (TFB) is located in the west-central portion of the Livermore site. In October 1998, a new ground water treatment system was installed at TFB replacing an ultraviolet/hydrogen peroxide (UV/H_2O_2) system had been in use since 1990. The new system, a more cost-effective large-capacity air-stripping system, passes effluent air from the air stripper through granular activated carbon to remove VOCs. The treated effluent air is vented to the atmosphere. Ground water is treated for chromium(VI) in an ion-exchange unit during the winter months, based on the current RWQCB discharge substantive requirements. This new system is designed to treat up to 75 gpm of ground water. Treated ground water from TFB is discharged into the north-flowing drainage ditch parallel to Vasco Road that empties into Arroyo Las Positas to the north. TFB was in compliance throughout 1998. Three new wells were drilled and completed at TFB during 1998 (**Table 8-3**).

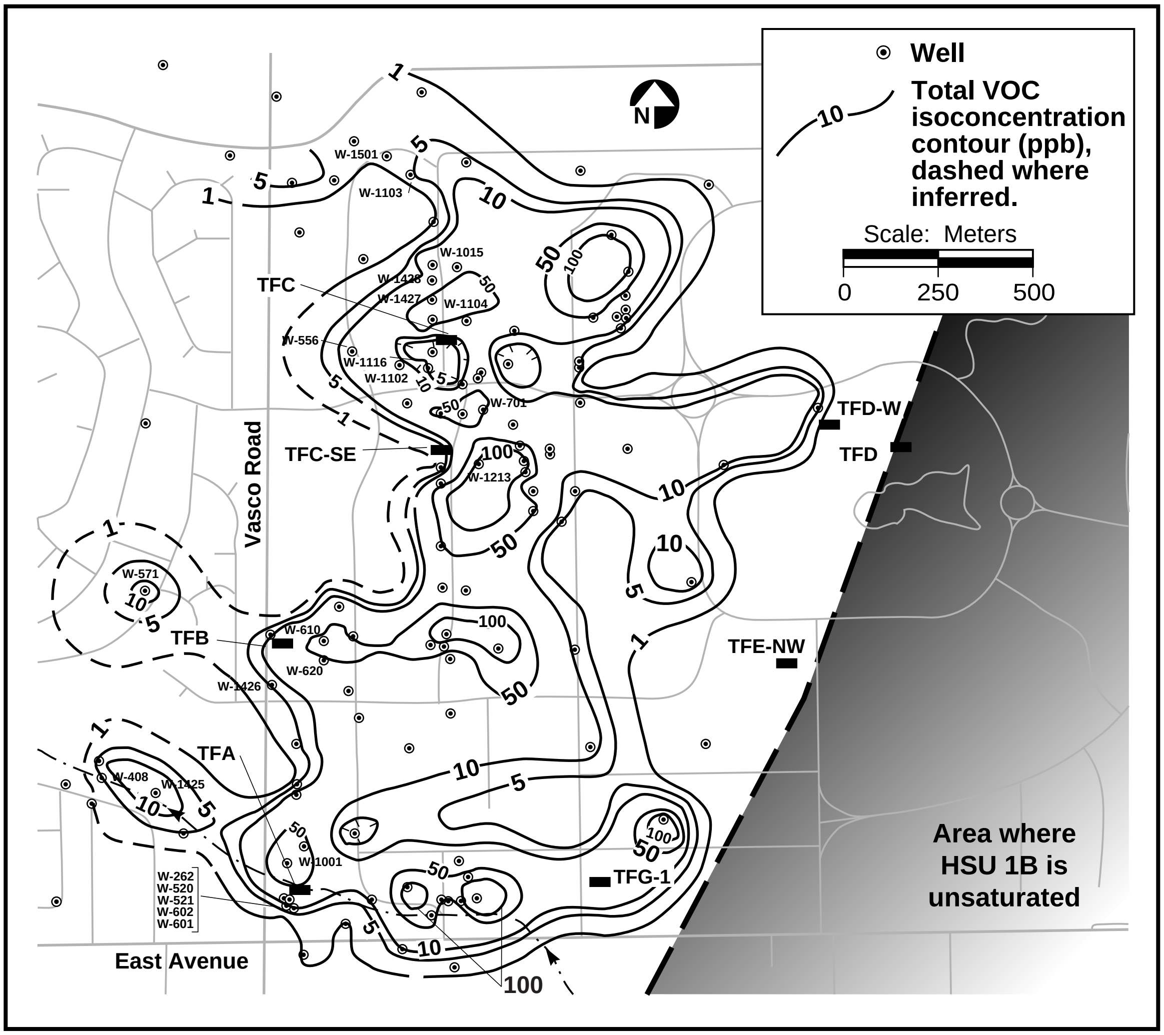


Figure 8-3. Isoconcentration contour map of total VOCs within hydrostratigraphic unit (HSU) 1B.

Treatment Facility C

Treatment Facility C (TFC) is located in the northwest quadrant of the Livermore site (**Figure 8-1**). Portable Treatment Unit (PTU) location TFC Southeast (TFC-SE), located near the intersection of Avenue A and Sixth Street in the northwest quadrant of the Livermore site, treats ground water from one HSU 1B well (W-1213). The combined TFC facilities operated at flow rates ranging from 47 to 55 gpm in 1998. TFC and TFC-SE process VOCs in ground water using air stripping. The effluent air from the stripper is treated with granular activated carbon prior to discharge to the atmosphere. Ground water is treated for chromium(VI) in an ion-exchange unit during the winter months,

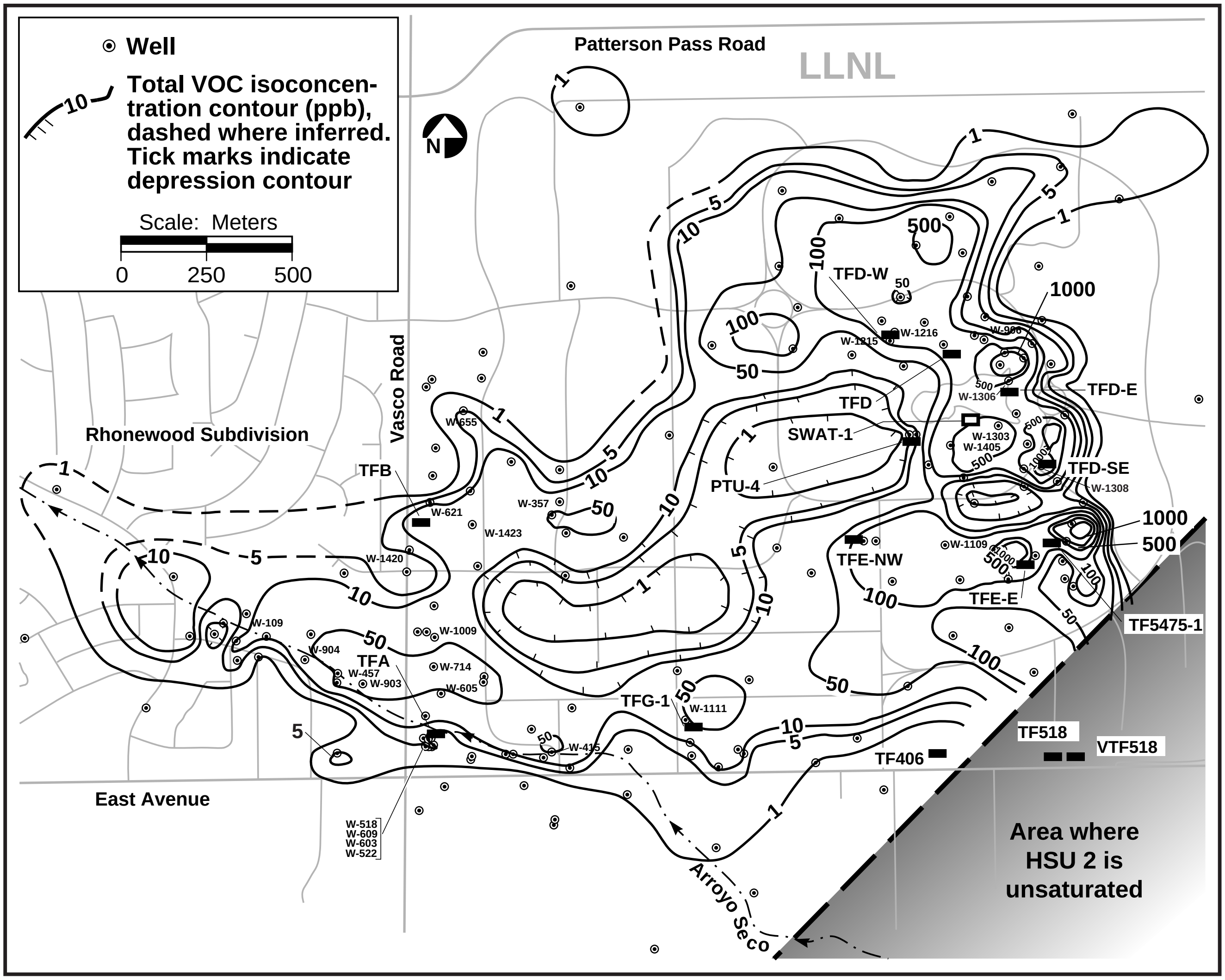


Figure 8-4. Isoconcentration contour map of total VOCs within hydrostratigraphic unit (HSU) 2.

based on the current RWQCB discharge substantive requirements. Treated ground water from TFC is discharged into a north-flowing drainage ditch that empties into Arroyo Las Positas. Treated ground water from TFC-SE is discharged into a storm sewer that empties into Arroyo Las Positas to the north. TFC was in compliance with all permits throughout 1998. Three new wells were drilled and completed at TFC during 1998.

Treatment Facility D

Treatment Facility D (TFD) is located north of the Drainage Retention Basin (DRB) in the east-central portion of the Livermore site (**Figure 8-1**). In 1998, TFD was expanded to include permanent connections for extraction wells W-1206 and W-1208. Dual screened

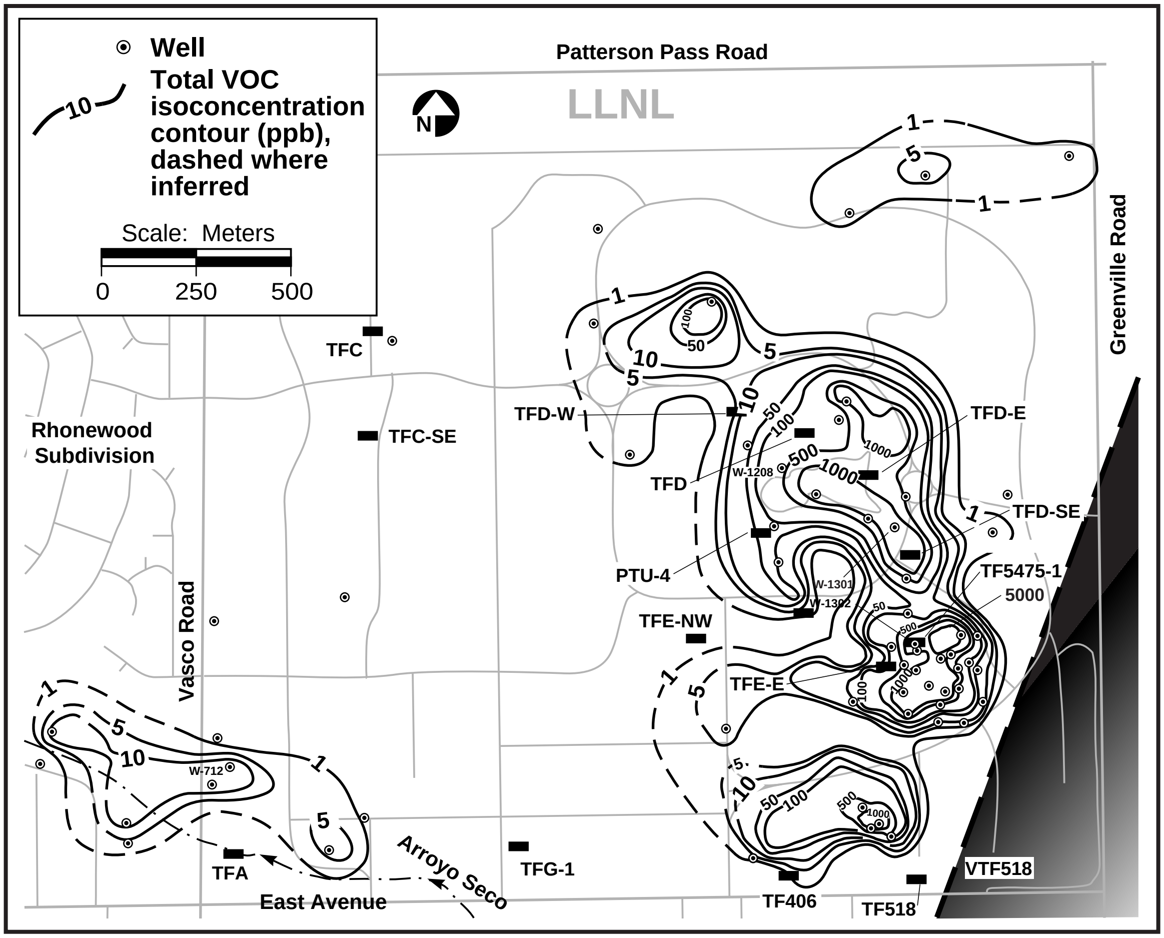


Figure 8-5. Isoconcentration contour map of total VOCs within hydrostratigraphic unit (HSU) 3A.

well, W-907, has a packer set to enable extraction from the lower screened interval (HSU 5) only. One new extraction location, TFD Southeast (TFD-SE), which is located south of the East Traffic Circle and east of Inner Loop Road, was activated in March 1998. Portable treatment unit (PTU) 11 was used to meet the Remedial Action Implementation Plan (RAIP) milestone date. TFD-SE treats ground water from two extraction wells, including one HSU 2 well (W-1308) and one HSU 4 well (W-314).

Two other extraction locations, TFD West (TFD-W) and TFD East (TFD-E), continued to treat ground water in 1998 using PTUs. TFD-W is located south of North Inner Loop Road in the central portion of the Livermore site and TFD-E is located east of the DRB in the east-central portion of the Livermore site. TFD, TFD-W, TFD-E, and TFD-SE remove VOCs by air stripping. The effluent air from the stripper is treated with granular activated carbon before it is vented to the atmosphere. Treated ground water from TFD and TFD-E is discharged either into the DRB or into an underground pipeline

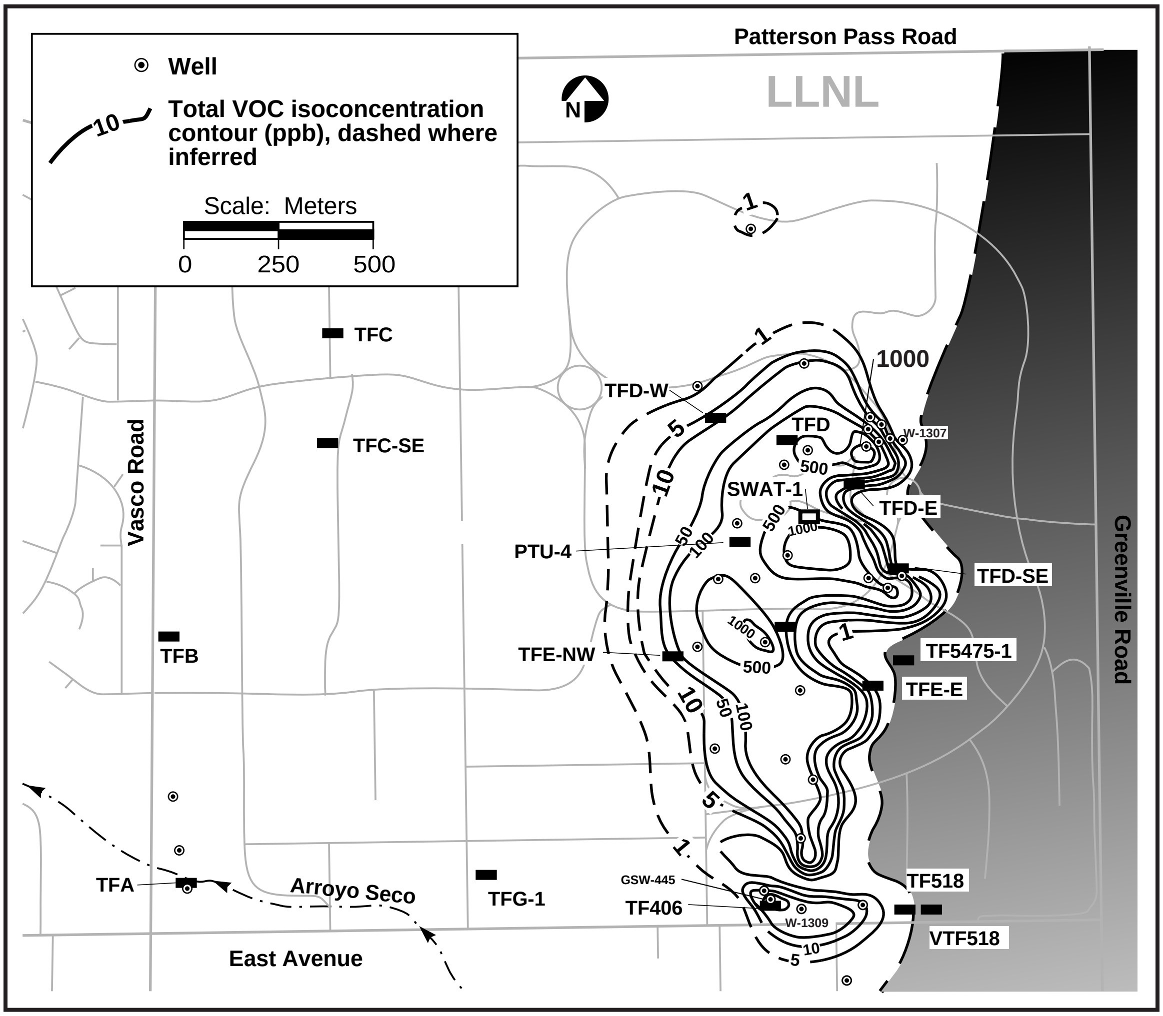


Figure 8-6. Isoconcentration contour map of total VOCs within hydrostratigraphic unit (HSU) 4.

downstream of the DRB weir and flows northward to Arroyo Las Positas. Treated ground water from TFD-W is discharged into a nearby storm sewer that also empties into Arroyo Las Positas. Treated ground water from TFD-SE is discharged into a lined drainage ditch, which flows northwest into the DRB. All TFD facilities were in compliance throughout 1998.

The TFD area extraction wells hydraulically control VOCs in HSUs 2, 3A, 4, and 5. Distal VOC plumes in the western TFD area should be hydraulically controlled once the planned TFC-East and TFC-Northeast treatment facilities are activated.

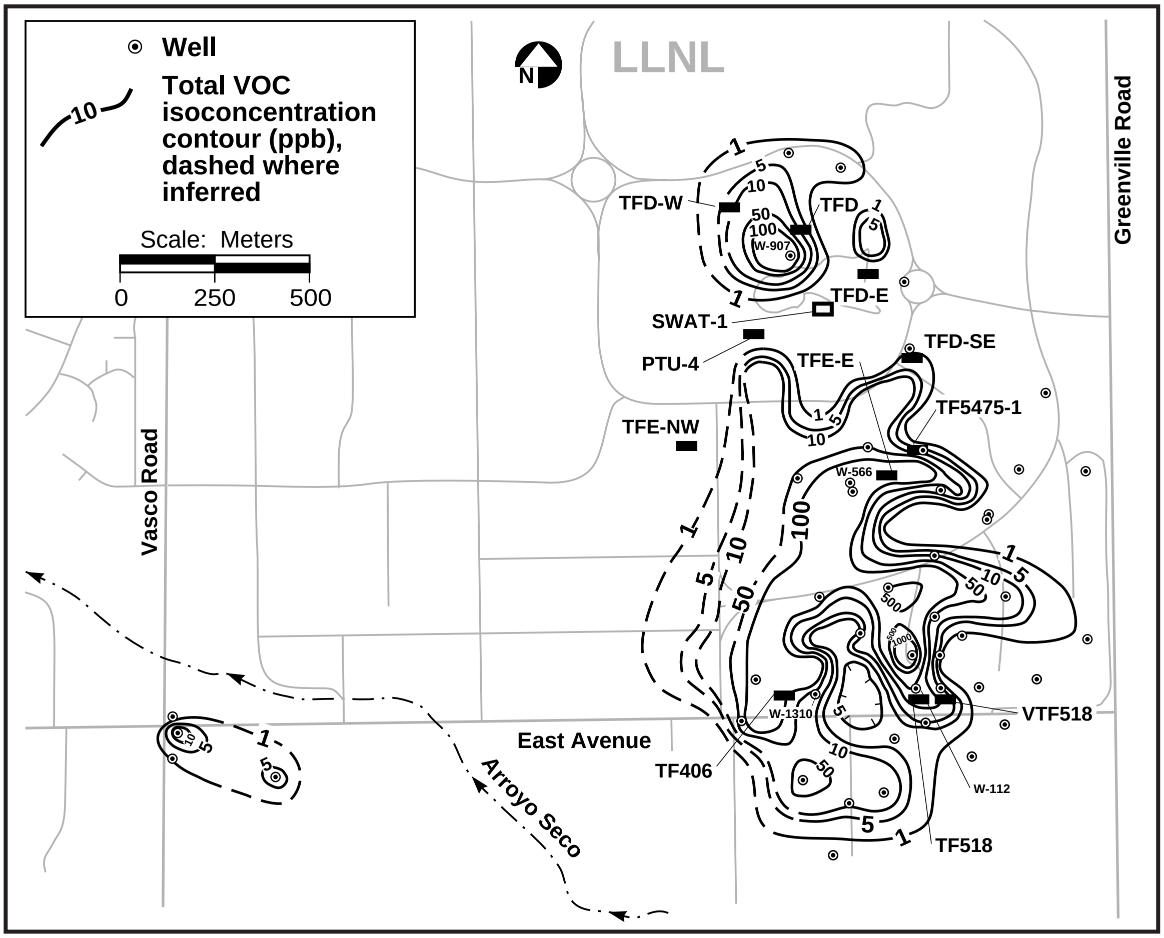


Figure 8-7. Isoconcentration contour map of total VOCs within hydrostratigraphic unit (HSU) 5.

In 1998, one-hour drawdown tests were conducted on TFD area wells W-1408, W-1416, W-1417, and W-1421. Eight-hour, step-drawdown tests were performed on proposed extraction wells W-1417, W-1419, and W-1421 to evaluate their effectiveness (see Aarons et al. 1998).

Following the successful treatability test conducted at TFD in 1997, the solar-powered water activated-carbon treatment (SWAT) unit was reconnected to well W-361, located south of the DRB in September 1998. The SWAT uses a solar-powered pump to extract ground water, which is then passed through a series of three 55-gal granular activated carbon canisters for treatment. The treated ground water was discharged to the DRB. During 1998, the SWAT unit treated about 0.3 ML of ground water containing an estimated 0.6 kg of VOCs.

Table 8-2. 1998 extraction wells and extraction rates.

Treatment facility area	Hydrostratigraphic unit	Extraction wells	Extraction rate (gpm)
TFA	HSU 1B	W-109, W-415, W-457, W-518, W-522, W-603, W-605, W-609, W-614, W-714, W-903, W-904, W-1009	179–362
	HSU 2	W-262, W-408, W-520, W-601, W-602, W-1001, W-1004	
	HSU 3A	W-712	
TFB	HSU 1B	W-357, W-621, W-655	39–60
	HSU 2	W-610, W-620, W-704	
TFC	HSU 1B	W-701, W-1015, W-1102, W-1103, W-1104, W-1116, W-1213	47–55
TFD	HSU 1B	W-361	111–163
	HSU 2	W-906, W-1215, W-1216, W-1303, W-1306, W-1308	
	HSU 3A	W-1208, W-1301	
	HSU 4	W-1307	
	HSU 5	W-907, W-1218, W-1220	
TFE	HSU 2	W-566, W-1109	18–47
	HSU 5		
TF406	HSU 4	GSW-445, W-1309	13–34
	HSU 5	W-1310	
TFG	HSU 2	W-1111	6.5–8
TF5475		W-1302	1–2
TF518	HSU 5		5–23
	HSU 6	W-112, W-211	
VTF518		SVI-518-201, SVI-518-303	20–50 (scfm)
	1998 Total		420–754 20–50 (scfm)

Notes:

kg = Kilograms.

gpm = Gallons per minute.

scfm = Standard cubic feet per minute.

Table 8-3. Wells installed in 1998.

Treatment facility area	Hydrostratigraphic unit	Extraction wells
TFA	HSU 1B	W-1425
	HSU 2	W-1424
TFB	HSU 1B	W-1426
	HSU 2	W-1420, W-1423
TFC	HSU 1B	W-1427, W-1428, W-1501
TFD	HSU 2	W-1416, W-1419, W-1502
	HSU 3A	W-1408, W-1417, W-1504
	HSU 4	W-1421, W-1503
TFE	HSU 2	W-1409
	HSU 3A	W-1422
	HSU 4	W-1418
TF406	HSU 4	W-1411
	HSU 5	W-1410
TF518	HSU 3A	W-1412, W-1414
	HSU 5	W-1413
TF5475	HSU 2	W-1415

An additional PTU was operated at wells W-1220 and W-1218 from March 1998 to November 1998 in the southern part of the TFD area to expedite VOC mass removal and site cleanup. Wells W-1220 and W-1218 pumped at a combined flow rate of about 90 L/min, and treated about 2.6 ML of ground water containing an estimated 2.4 kg of VOCs. Eight new wells were drilled and completed at TFD during 1998 (**Table 8-3**).

Treatment Facility E

The TFE area is located in the southeastern quadrant of the Livermore site (**Figure 8-1**). In 1998, TFE East (TFE-E) continued treating ground water using a PTU. TFE-E is located in the east-central portion of the Livermore site. One additional extraction location, TFE Northwest (TFE-NW), which uses a PTU, was activated in 1998. TFE-NW, treats ground water from extraction wells in HSU 2 and HSU 4 and is located south of the Inner Loop Road, immediately west of Southgate Drive. TFE-E and TFE-NW process ground water for treatment of VOCs using an air stripper, and the effluent air is treated using granular activated carbon to remove VOCs before it is vented to the atmosphere. Treated ground water from TFE-E is discharged into a drainage ditch that flows north into the DRB. Treated ground water from TFE-NW is discharged into a storm drain that flows north into Arroyo Las Positas. TFE-E and TFE-NW were in compliance throughout 1998.

In the TFE area, the TFE-E extraction wells provide hydraulic containment of some portions of VOC plumes in HSUs 2, 4, and 5. The VOC plumes in HSUs 3A, 4, and 5, located in the western and southern TFE areas, should be hydraulically controlled once the TFE-Southwest, TFE-Southeast, and TFE-West treatment facilities are operating. The planned start-up dates for these treatment facilities are March and June of 2000, and January 2001, respectively.

An additional PTU was operated at wells W-1418 and W-1422 in December 1998 in the northern part of the TFE area to expedite VOC mass removal and site cleanup. Pumping at these wells is planned to continue into 1999. During 1998, wells W-1418 and W-1422 pumped at a combined flow rate of about 38 L/min, and treated about 0.5 ML of ground water containing an estimated 0.9 kg of VOCs. Three new wells were drilled and completed at TFD during 1998 (**Table 8-3**).

Treatment Facility G

Treatment Facility G (TFG) is located in the south-central portion of the Livermore site (**Figure 8-1**). Treatment Facility G-1 (TFG-1) is located near Avenue B, about 90 m north of East Avenue in the south-central part of the Livermore site. TFG-1 treats ground water for VOC treatment using an air stripper, and the effluent air is treated using granular activated carbon to remove VOCs before it is vented to the atmosphere. Ground water is treated for chromium(VI) in an ion-exchange unit. Under the current RWQCB discharge substantive requirements, water from TFG-1 requires treatment for chromium(VI) only during the winter months. Treated ground water from TFG-1 is discharged to a storm drain located about 50 ft north of TFG-1, which empties into Arroyo Seco. TFG-1 was in compliance throughout 1998. No boreholes or wells were drilled, and no hydraulic tests were conducted in the TFG area during 1998.

Since January 1998, a treatability study using granular activated carbon to treat ground water from extraction well W-1111 has been underway. Three 180-kg granular activated carbon canisters in series are used to process water from well W-1111. The existing PTU was used for backup treatment during the test to ensure that no VOCs were discharged. Breakthrough of the first carbon canister occurred after three months of operation. At the time of breakthrough, 2.6 ML of ground water had already been treated. The granular activated carbon treatment unit (GTU) has proved to be effective and efficient. Based on the results of the test, a GTU unit will replace the PTU at TFG-1 in 1999.

Treatment Facility 406

Treatment Facility 406 (TF406) is located east of Southgate Drive near East Avenue in the south-central part of the Livermore site. TF406 treats ground water to remove VOCs using an air stripper. The effluent air is passed over granular activated carbon to remove VOCs before it is vented to the atmosphere. All treated ground water was discharged to a storm drain that flows to Arroyo Las Positas. TF406 was in compliance throughout 1998.

When activated in 1996, TF406 processed ground water from extraction wells GSW-445 and W-1114. In 1997, well W-1114 was destroyed and two new extraction wells, W-1309 and W-1310 were installed. TF406 began processing ground water from wells W-1309 and W-1310 in February 1998. Cumulative flow from the three extraction wells is about 100 L / min.

Passive bioremediation to remediate fuel hydrocarbons continued in the TF406 area during 1998 in HSUs 3A and 3B. Active ground water extraction and treatment for residual dissolved fuel hydrocarbons at Treatment Facility F was discontinued in 1996 with regulatory agency concurrence (San Francisco Bay Regional Water Quality Control Board 1996).

The TF406 extraction wells provide significant hydraulic control of VOC plumes in HSUs 4 and 5 in the TF406 area. The VOC plumes in HSUs 3A, 4, and 5 should be hydraulically controlled once treatment facilities at TF406-Northwest and TF518-North are installed. Two new wells were drilled and completed at TF406 during 1998 (**Table 8-3**).

Ground Water Treatment Facility 518

Treatment Facility 518 (TF518) is located in the southeastern quadrant of the Livermore site, north of East Avenue and near Avenue H, adjacent to VTF518 (**Figure 8-1**). TF518 was constructed in 1997 and began operating in January 1998. In 1998, TF518 treated ground water from two extraction wells, W-112 (HSU 5) and W-211 (HSU 6).

Pumping from well W-211 was discontinued in May 1998 after six consecutive sampling events between September 1997 and April 1998 showed TCE concentrations remained below the 5 ppb maximum contaminant level (MCL). An additional sample taken four months after pumping ceased indicated that concentrations in the well remain below the MCL. Quarterly sampling of well W-211 will continue in 1999.

In July 1998, the first miniature portable treatment unit (MTU-1) was activated in the TF518 area, replacing the full-size PTU that had been in operation since January 1998. Both the units remove VOCs by means of an air stripper, and treat effluent air using granular activated carbon to remove VOCs. All treated ground water is discharged to a storm drain that ultimately empties into Arroyo Las Positas. TF518 was in compliance throughout 1998. Three new wells were drilled and completed at TF518 during 1998 (**Table 8-3**).

Treatment Facility 5475

The Treatment Facility 5475 (TF5475) area is located in the southeastern quadrant of the Livermore site where tritium is present in HSU 3A ground water in concentrations above the MCL. TF5475-1 which was activated in September 1998, uses down-hole, in situ catalytic reductive dehalogenation (CRD) to treat VOCs in ground water. This technology is based upon the reaction of dissolved hydrogen, introduced to the ground water through a hydrophobic membrane, with VOCs on a palladium-alumina catalyst to form ethane and chloride. Because of the high CRD reaction rates, water is treated in one pass through the unit, and the treatment unit can be placed in the well casing. This technology treats VOCs in ground water while keeping the tritium in the subsurface.

The CRD unit operates in extraction well W-1302, a dual-screened well in which the unit extracts ground water from the lower screened interval and injects treated ground water containing tritium into the upper screened interval. TF5475-1 was in compliance throughout 1998. One new well was drilled and completed at TF5475 during 1998 (**Table 8-3**).

Vapor Treatment Facility 518

Vapor Treatment Facility 518 (VTF518) is located in the southeastern quadrant of the Livermore site. Soil vapor is extracted from the vadose zone, and VOCs are removed from the vapor using granular activated carbon canisters. Following treatment, the effluent air is discharged to the atmosphere. VTF518 was in compliance with the Bay Area Air Quality Management District permit throughout 1998.

Two instrumented membrane system (IMS) sampling/monitoring wells, SEA-518-301 and SEA-518-304, continue to monitor vadose zone remediation in the VTF518 area. The IMS system is used to collect vapor pressure, soil temperature, soil moisture, and soil vapor concentration data at various discrete depths. VOC vapor concentrations at SEA-518-301, the IMS borehole nearest VTF518 vapor extraction well SVI-518-201, have declined from an average of 111 parts per million by volume (ppmv) in September 1995 to an average of 6.7 parts per million volume (ppmv) in the upper zones (6, 15, 26, and 37 ft) in September 1998. However, an increase in vapor concentration has recently been observed in the lowest zone at 85 ft, from 143 ppmv in September 1995 to 220 ppmv in September 1998. Monitoring of the vadose zone will continue to evaluate the progress of remediation of the vadose zone in the VTF518 area. No new vapor treatment wells were drilled at VTF518 during 1998.

Ground Water Flow and Transport Modeling

Ground water flow and transport models are used at the Livermore site to support remediation system design and performance evaluation; to support ongoing subsurface characterization activities; and improve LLNL's ability to forecast, monitor, and interpret the progress of the ground water remediation program. In 1998, development continued on our three-dimensional ground water model for the Livermore site. The three-dimensional model builds vertical resolution into the two-dimensional model previously developed for the Livermore site (Tompson et al. 1995).

Treatment Facility A and B Model

In 1998, LLNL continued to use the three-dimensional ground water flow and contaminant transport model of HSUs 1B and 2 to evaluate perchloroethene (PCE) and trichloroethene (TCE) transport in the TFA and TFB areas. The development of this model is described in detail in Demir et al. (1997) and Vogele et al. (1996). This model, developed using the CFEST (Coupled Flow, Energy and Solute Transport) computer code (Gupta 1987), was calibrated to measured ground water elevation data collected from Livermore site monitoring wells.

In 1998, the model was used to compare simulated contaminant transport to ground water concentrations observed from 1996 through 1998. These simulations comprised a series of remedial pumping time steps that were constructed to reflect changes in extraction-well flow rates. Results from the preliminary simulations were within plausible uncertainty limits of the model.

Sitewide Model for all HSUs

In 1998, work continued to develop a three-dimensional ground water flow and transport model for all Livermore site HSUs using the FEFLOW (Finite Element subsurface FLOW system) computer code (Diersch 1998). To improve the accuracy of simulations and to better simulate contaminant migration in the source areas, all available subsurface hydraulic property data are being analyzed.

In 1998, work on the sitewide model consisted of improving the hydrogeological input data sets and beginning the flow calibration. The improvements of the hydrogeological data sets focused primarily on three major areas. First, the migration history of individual plumes was evaluated. As a result of this work, plume maps for 11 individual VOC constituents and total VOCs were generated for each quarter from 1987 to 1998 and displayed through a web-based graphical interface for analysis. Second, a revised set of HSU correlations across the entire eastern Livermore Basin was developed and put into the model. Third, heterogeneity within HSUs was evaluated by reviewing lithologic, geophysical, and hydraulic test data to better define the distribution of hydraulic conductivity within HSUs across the site.

Trailer 5475 Model

In 1998, LLNL developed a two-dimensional FEFLOW model of the Trailer 5475 area to evaluate the use of recirculation cells with the deployment of the catalytic reductive dehalogenation (CRD) treatment units. The objective of the model is to evaluate different potential extraction and injection well configurations to improve overall remediation performance. This effort is part of an ongoing evaluation of the T5475 area for use with engineering design and long-term planning.

Zone 7 Project

In 1997, the Alameda County Flood Control and Water Conservation District, Zone 7 (Zone 7) approached LLNL about using the existing LLNL ground water models to assist Zone 7 evaluate future ground water use in the basin surrounding LLNL. LLNL submitted a report to Zone 7 (Hoffman and Bishop 1998) on February 28, 1998 and presented the results to the Zone 7 Board on March 5, 1998. The report summarized the results of an investigation to estimate the subsurface volume of ground water and the volume of potential subsurface storage in the basin to address short- and long-term water resources management issues. A volumetric calculation was performed to determine the volume of potential ground water storage in the basin, and a potential drawdown or buildup of ground water in the area of interest. The existing two-dimensional CFEST flow model (Tompson et al. 1995) was used to estimate the volume of ground water flow in the basin, and to evaluate the influence of different rates of extraction and reinjection within the basin. The results of this analysis indicated about 1000 acre/ft of ground water flow through the basin with about 2000 to 5000 acre/ft of additional ground water storage.

Regulatory Compliance

In 1998, DOE/LLNL submitted documents required by CERCLA and the Livermore site Federal Facility Agreement (FFA). In addition, DOE/LLNL continued environmental restoration and community activities as discussed below.

CERCLA Documents

During 1998, DOE/LLNL issued two CERCLA documents for the Livermore site specified in the amended schedule in the RAIP (Dresen et al. 1993). Both Draft Final and Final Remedial Design Report No. 4 (RD4) (Berg et al. 1998) were submitted ahead of schedule. Submission of RD4 marked the successful completion of all primary FFA document milestones until the second Five-Year Review in August 2002.

As required by the FFA, DOE/LLNL issued the *LLNL Ground Water Project 1997 Annual Report* (Hoffman et al. 1998) on March 31, 1998. DOE/LLNL also finalized and issued seven Remedial Project Managers' (RPMs') meeting summaries. The March RPM summary (Bainer and Littlejohn 1998a) included quarterly self-monitoring data. Subsequent 1998 quarterly self-monitoring data were reported in letter reports (Bainer and Littlejohn 1998b, 1998c, 1999). LLNL also updated the Quality Assurance Project Plan and is in the process of responding to the U.S. Environmental Protection Agency (EPA) comments.

An Action Memorandum for an emergency removal action was issued February 2, 1998 (Bainer and Berg 1998) in response to a discovery of undocumented buried capacitors containing polychlorinated biphenyls (PCBs) during excavation for the National Ignition Facility (NIF) in the northeast corner of the Livermore site. As part of the work on the GWP, LLNL also prepared sections of NIF quarterly progress reports pursuant to an agreement specified in the Joint Stipulation and Order, in partial settlement of a Natural Resources Defense Council (NRDC) vs Pena DOE lawsuit.

LLNL prepared a sampling plan for determining the extent of elevated plutonium concentrations in soil in Livermore's Big Trees Park (U.S. Department of Energy and Lawrence Livermore National Laboratory 1998). This plan and the associated sampling and analyses were LLNL's voluntary response to community concerns expressed in the Agency for Toxic Substances and Disease Registry/California Department of Health Services (CDHS) Environmental Health Investigations Branch's February 1998 draft Public Health Consultation. See Chapter 10, Soil and Sediment Monitoring, for details.

Community Relations

The Community Work Group (CWG) met once in 1998 to discuss the DOE budget, progress on the Livermore site cleanup, and the Livermore site Priority List/Consensus Statement. Correspondence and communication with CWG members continued throughout the year. DOE/LLNL met three times with members of Tri-Valley Citizens Against a Radioactive Environment and their scientific advisor as part of the activities funded by an EPA Technical Assistance Grant

Other Livermore site community relations activities in 1998 included communications and meetings with neighbors; local, regional and national interest groups; and other community organizations. LLNL also conducted public presentations including those to local realtors and to national and northern California peace leaders; produced and distributed the *Environmental Community Letter*; maintained the information repositories and administrative record; conducted tours of site environmental activities; and responded to public and news media inquiries.

Environmental Impact

Based on a comparison of 1998 and 1997 annual isoconcentration maps (Hoffman et al. 1998), a number of trends in VOC concentrations are evident.

1. In the TFA area, along the western margin of the site, total VOC concentrations east of Vasco Road near newly activated extraction well W-1001 (HSU 1B) declined below 100 ppb for the first time (**Figure 8-3**). Off-site HSU 1B concentrations remained below the MCL for all contaminants of concern except for well W-1425, where PCE concentrations were 8.3 ppb in September 1998. Total VOC concentrations in HSU 2 declined from over 100 ppb to around 50 ppb near extraction well W-415, and the 50 ppb total VOC contour in HSU 2 is now east of extraction well W-904 (**Figure 8-4**).

2. VOC concentrations in the western part of the TFB HSU 1B plume continued to decline, while concentrations around the TFB source area remained relatively unchanged (**Figure 8-3**). VOC concentrations in HSU 2 in the TFB area also remained relatively unchanged in 1998 (**Figure 8-4**).

3. In the northwestern TFC area, concentrations of VOCs declined from over 100 ppb to about 50 ppb around extraction well W-1104 (**Figure 8-3**). Concentrations in the TFC-SE area remain relatively unchanged from 1997.

4. In the TF406 area, along the southern margin of the Livermore site, VOC concentrations are relatively unchanged in HSU 4 since 1997 (**Figure 8-4**). Total VOC concentrations in HSU 5 south of the Livermore site boundary declined from over 150 ppb to below 75 ppb in 1998 (well W-509, August 21, 1998 data) (**Figure 8-7**). In the TFG area south of the Livermore site boundary, total VOC concentrations in HSU 2 declined from a high of about 39 ppb to about 9 ppb total VOCs in 1998 (piezometer SIP-212-101, July 13, 1998 data) (**Figure 8-4**).

5. In the eastern and southeastern TFD areas, total VOC concentrations in HSU 2 are beginning to decline as shown by the smaller area encompassed by the 500 total VOC ppb contour (**Figure 8-4**). Total VOC concentrations in HSU 3A in the eastern and southeastern part of the Livermore site remain relatively unchanged.

6. Total VOC concentrations in both HSU 4 and HSU 5 in the eastern part of the Livermore site remained relatively unchanged in 1998 (**Figures 8-6** and **8-7**). However, data from 1998 drilling indicate that there is an additional area of high concentration (over 1500 ppb total VOCs) in HSU 4 in the TFD / TFE-NW area. A PTU will treat ground water in this high concentration area from HSU 4 monitor well W-1418 in 1999.

Site 300 Ground Water Project

Environmental investigations and cleanup activities at Site 300 began in 1981. Site 300 became a CERCLA / Superfund site in 1991, when it was placed on the National Priorities List (NPL). The CERCLA environmental restoration study areas are shown in **Figure 8-8**. The major contaminants of concern are listed in **Table 8-4**.

Geology of Site 300

Site 300 is located in the sparsely populated Altamont Hills, which are part of the Coast Ranges Physiographic Province and separate the Livermore Valley to the west from the San Joaquin Valley to the east. Site 300 stratigraphy is shown in **Figure 8-9**. Rocks exposed in the region are classified into three groups:

- Late Tertiary-Quaternary (0–5 million years ago)—alluvium and semilithified sediments, mainly of continental origin.
- Early to late Tertiary (5–65 million years ago)—shallow marine and continental sedimentary and volcaniclastic rocks.
- Jurassic-Cretaceous (65–180 million years ago)—Great Valley sequence (marine sedimentary rocks and ophiolites) and Franciscan Complex (sheared and variably metamorphosed sedimentary and igneous rocks).

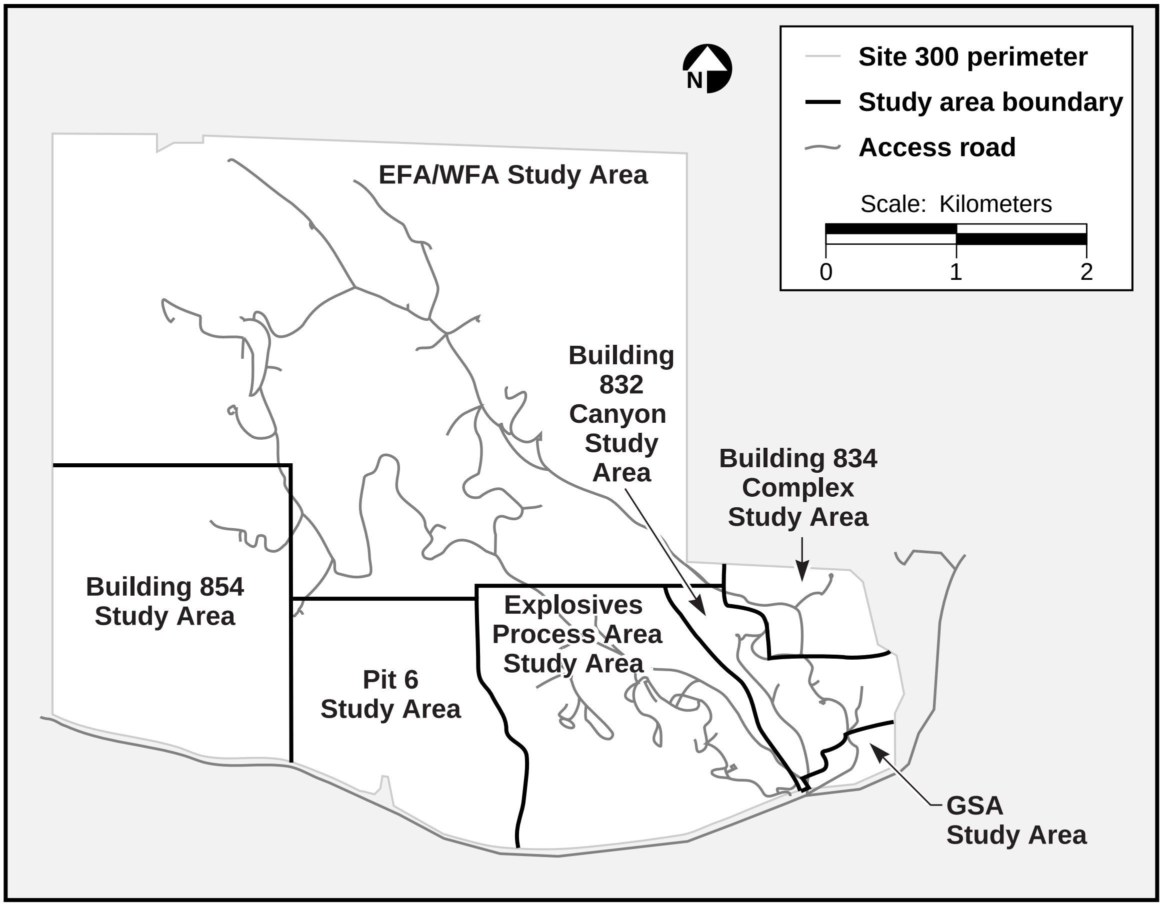


Figure 8-8. Environmental restoration study areas at Site 300.

Distinctive blue-gray to brown weathering volcaniclastic sandstone and sandy siltstone, interbedded with light gray weathering tuffaceous claystone and conglomerate, are exposed extensively within Site 300. These rocks are mapped as the late Miocene Neroly Formation (Huey 1948; Dibblee 1980). The Neroly Formation is also present in the subsurface beneath the southeastern portion of Site 300.

The Neroly Formation is the principal hydrologic unit within Site 300 and has therefore been the focus of the detailed geologic and hydrogeologic studies conducted during recent years (summarized in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300,* hereafter referred to as Final SWRI Report [Webster-Scholten 1994]). The complete section of the Neroly Formation is about 150-m thick beneath Site 300.

Table 8-4. Major contaminants of concern found in soil, rock, and ground water at Site 300.

Study area	Contaminant of concern
General Services Area (GSA)	VOCs (primarily TCE)
Building 834 Complex	VOCs (primarily TCE), organosilicate oil, nitrate
Explosives Process Area	VOCs (primarily TCE) HE[(a)] (primarily HMX[[b]]) Nitrate, perchlorate
East and West Firing Areas (EFA/WFA)	Tritium Depleted uranium VOCs (primarily TCE) Nitrate, perchlorate
Building 854	VOCs (primarily TCE) Nitrate, perchlorate
Pit 6	VOCs (primarily TCE) Tritium, nitrate, perchlorate
Building 832 Canyon	VOCs (primarily TCE) Nitrate, perchlorate

a HE = high explosives.

b HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.

The floodplain of Corral Hollow Creek lies along the southern boundary of Site 300 and borders portions of the General Services Area (GSA), the Explosives Process Area, and the area of closed landfill Pit 6. Floodplain alluvium consists dominantly of coarse cobble and boulder-bearing terrace gravel derived from sources to the south, with lenses and local cappings of sandy silt and silty clay.

The bedrock sequence within Site 300 has been slightly deformed into several gentle, low-amplitude folds. The locations and characteristics of these folds, in combination with the regional fault and fracture patterns, locally influence ground water flow within the site and have therefore been studied in great detail as part of the CERCLA investigations.

Hydrogeology of Site 300

Site 300 is semiarid, with an average annual rainfall of 27 cm (10.5 in). The site is underlain by gently dipping sedimentary bedrock dissected by steep ravines. The bedrock comprises interbedded conglomerates, sandstones, siltstones, and claystones (see **Figure 8-9**).

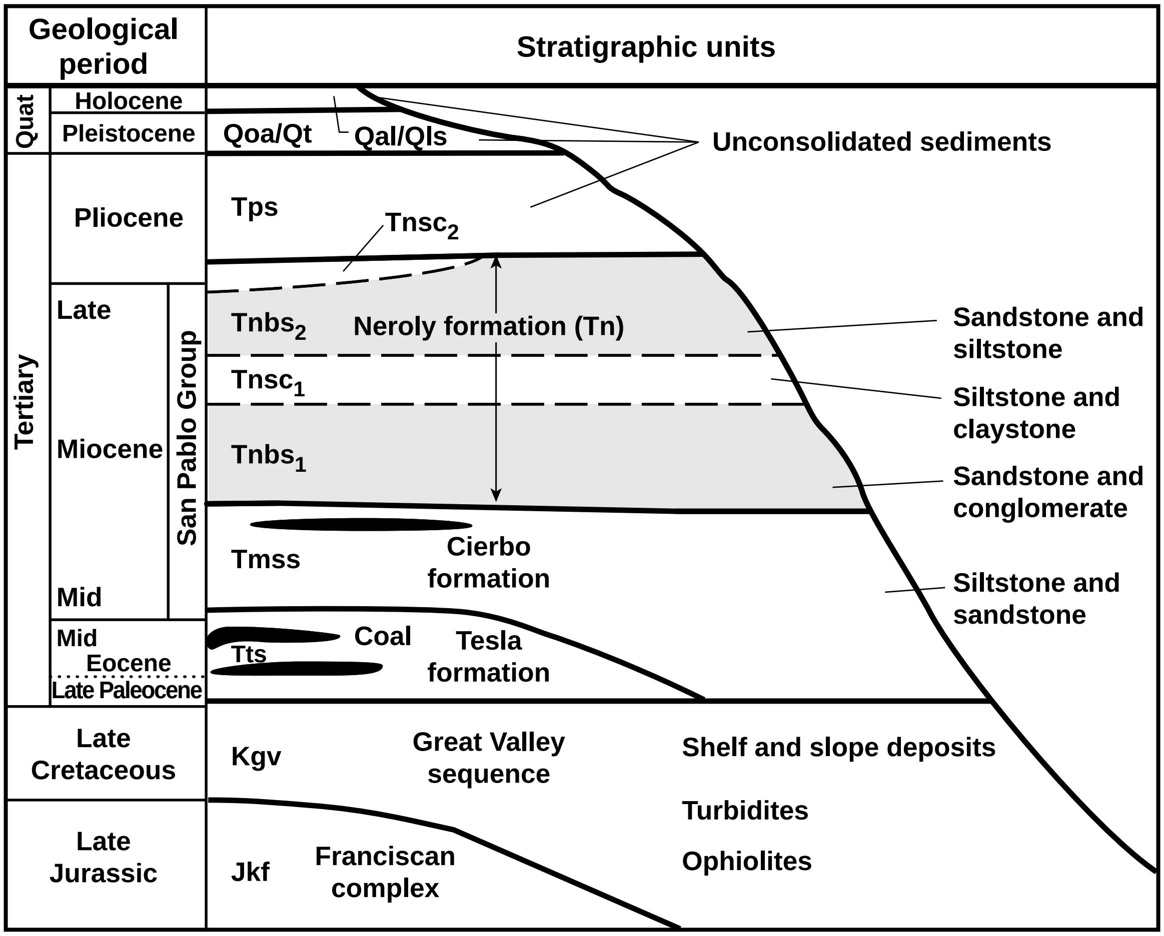


Figure 8-9. Site 300 stratigraphy (Webster-Scholten 1994).

Ground water primarily occurs in the Neroly Formation upper and lower blue sandstone units (Tnbs$_2$ and Tnbs$_1$) and in the underlying Cierbo Formation (Tmss). Ground water can also be present in permeable Quaternary alluvium valley fill (Qal) during the winter rainy season. Some ground water is present as perched water-bearing zones beneath hilltops. The perched water-bearing zones primarily occur in the unconsolidated sediments of the Miocene-age nonmarine unit (Tps) in the Building 833 and 834 areas and in the Explosives Process Area. However, an extensive perched water-bearing zone occurs in Tnbs$_1$ sandstones in the northwestern portion of the East and West Firing Area. Fine-grained siltstone and claystone interbeds in Tnbs$_1$ and Tmss act as aquitards, confining layers, or perching horizons. Portions of the bedrock section at Site 300 are abundantly fractured, and thus much of the ground water flow occurs in fractures as well as in pores. Ground water is present under confined conditions in the southern half of the site but is generally unconfined elsewhere. **Figure 8-10** is a map of the potentiometric surface for the first continuous water-bearing zone at Site 300, which principally occurs in the Neroly lower blue sandstone aquifer (Tnbs$_1$).

Recharge occurs where saturated alluvial valley fill is in contact with underlying permeable bedrock, and where bedrock strata crop out. Local recharge occurs on hilltops, creating the perched water-bearing zones in the Building 832, 834, and 854 areas. Low rainfall, high evapotranspiration rates, steep topography, and intervening aquitards generally preclude direct vertical recharge to the deeper bedrock aquifers.

Ground water flow in the bedrock follows the inclination, or dip, of the layers. The tectonic forces that uplifted the Altamont Hills faulted, gently folded, and tilted the once-horizontal sedimentary strata. A major structure, the east-west trending Patterson anticline, occupies a central location within the site. North of the anticline, bedrock dips east-southeast, and ground water flows generally east-northeast. South of the anticline, bedrock dips south-southeast, and thus ground water flows roughly south-southeast.

The Cierbo Formation (Tmss) is saturated beneath Doall Ravine, the Building 851 and 854 areas, and the southern part of the East Firing Area. Tmss is unsaturated or does not otherwise yield water to wells in other parts of the East and West Firing Areas. The thickness of the Cierbo Formation is not well-known because most boreholes are not deep enough to completely penetrate this formation. Some of the deeper wells in the GSA penetrate the uppermost Tmss. The continuity of saturation in the Tmss between the northwest and southeast areas of Site 300 is undetermined. Ground water in the Tmss occurs under unconfined to artesian conditions.

The Tps unit is the youngest bedrock unit identified at Site 300 and is generally present only on hilltops. Where present, ground water is frequently perched, discontinuous, and ephemeral. The exception to this condition exists in the Explosives Process Area, where the extent of saturation in Tps sediments is significant. Ground water in the Tps unit is generally unconfined, although water under confined conditions does occur locally.

Quaternary alluvium (Qal) is present as valley fill in ravines throughout Site 300 but is saturated only in the Corral Hollow Creek stream channel, in Doall Ravine in the West Firing Area, and in southern Elk Ravine in the East Firing Area near a spring. Saturated Quaternary terrace alluvium deposits (Qt) are present at Pit 6, the GSA, and in the Building 832 Canyon area; some of these ground water occurrences are ephemeral. Small quantities of ground water are present in some local landslide (Qls) deposits.

All ground water contaminant plumes at Site 300 occur in Neroly Formation (Tn) rocks, unamed Pliocene nonmarine sediments (Tps), or unconsolidated Quaternary sediments (Qal , Qls, or Qt) stratigraphic units. The extent of ground water contamination at Site 300 is shown on **Figure 8-11**.

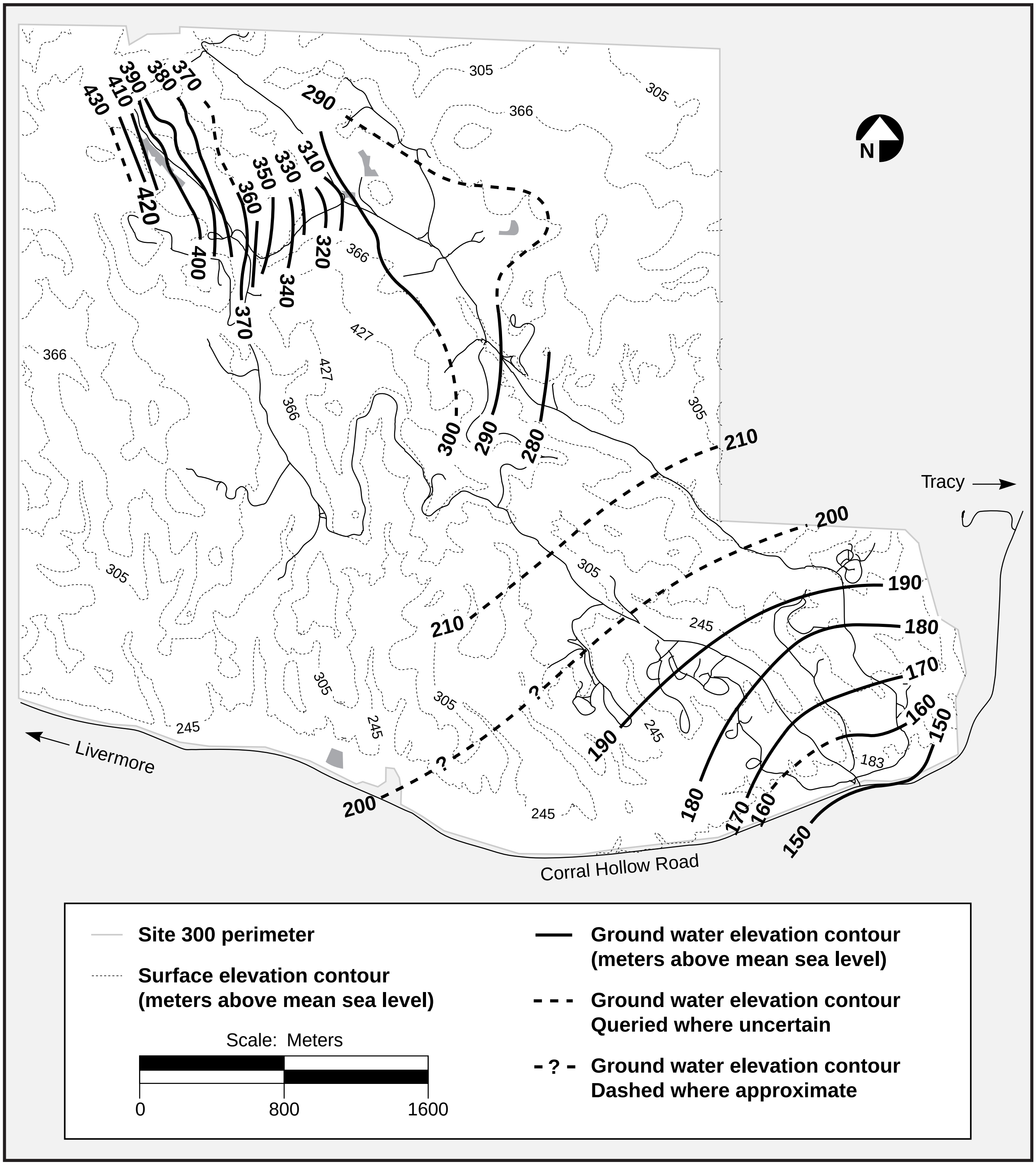


Figure 8-10. Approximate ground water elevations in the principal continuous water-bearing zone at Site 300.

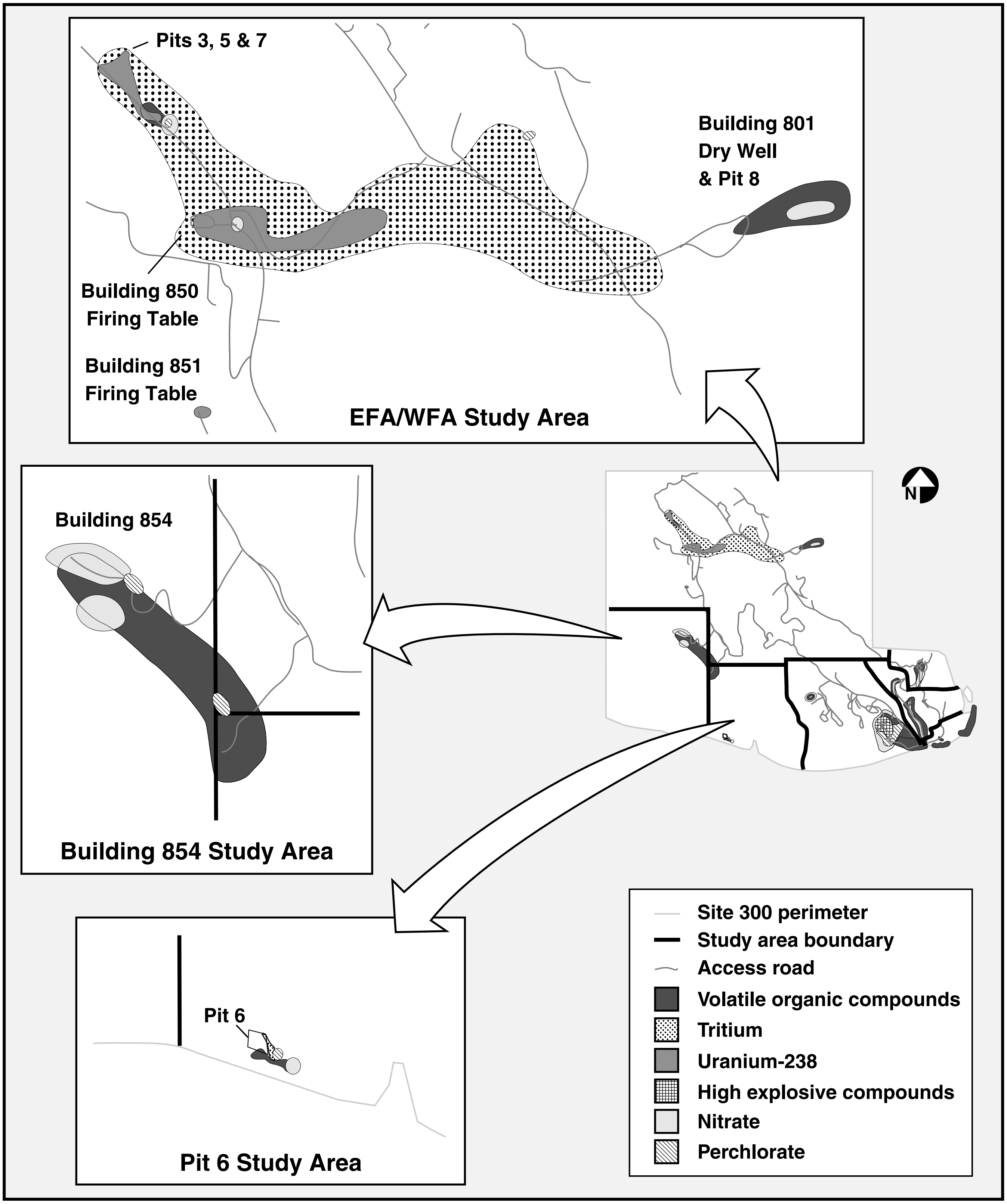
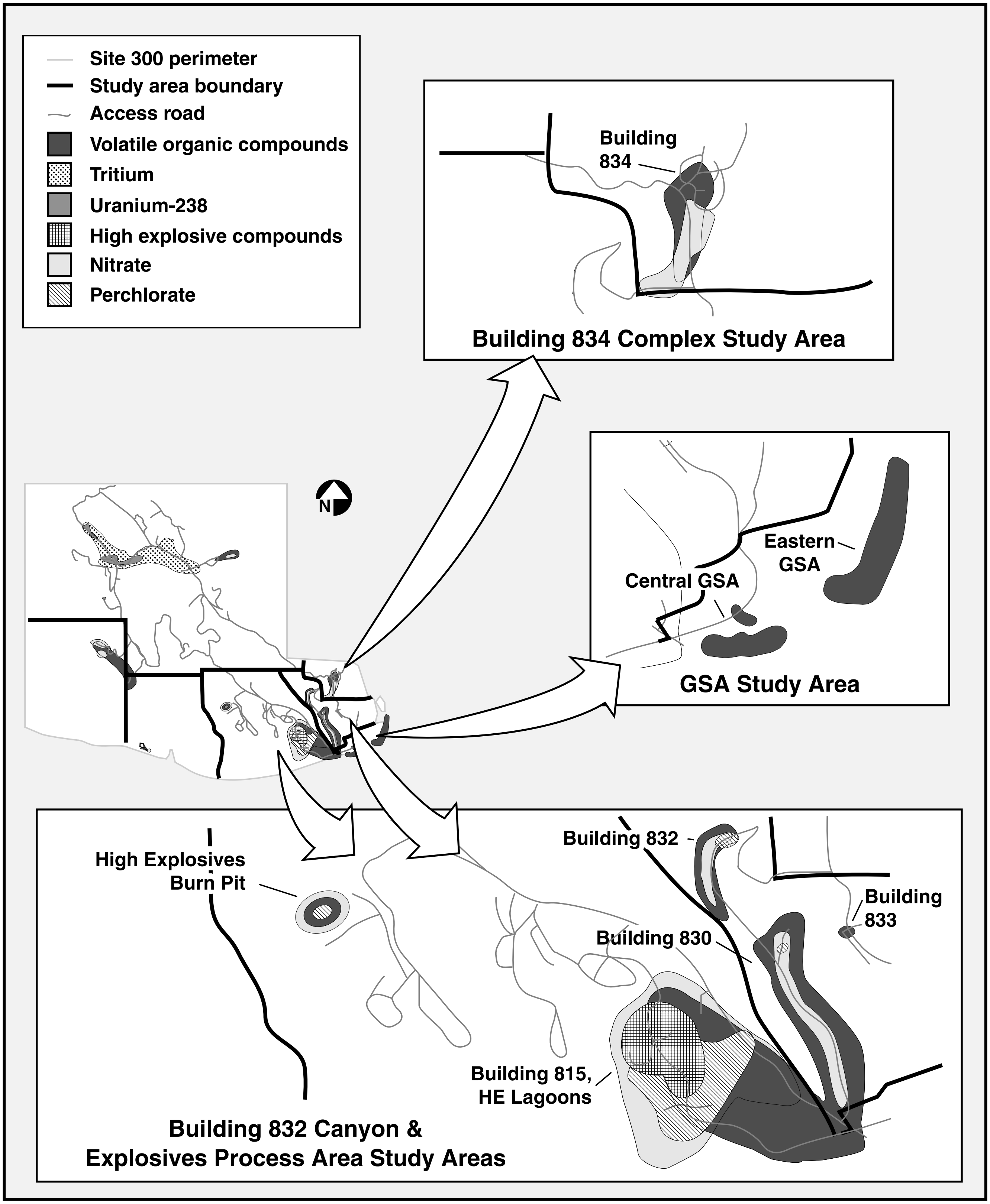


Figure 8-11. Extent of ground water contamination at LLNL Site 300.


Site 300 perimeter
Study area boundary
Access road
Volatile organic compounds
Tritium
Uranium-238
High explosive compounds
Nitrate
Perchlorate
Building 834
Building 834 Complex Study Area
N
Eastern GSA
Central GSA
GSA Study Area
High Explosives Burn Pit
Building 832
Building 833
Building 830
Building 815, HE Lagoons
Building 832 Canyon & Explosives Process Area Study Areas

8 Ground Water Investigation and Remediation

Study Area Highlights and Activities

Background information for LLNL environmental characterization and restoration activities at Site 300 can be found in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300* (Webster-Scholten 1994). Ground water remediation for Site 300 is discussed later in this chapter. See Chapter 9 for a discussion of 1998 ground water monitoring.

General Services Area

In the General Services Area (GSA), past leaks of solvents from storage areas and other facilities have resulted in several plumes of VOCs in ground water. Two ground water TCE plumes and two corresponding treatment facilities are present at both the eastern and central GSA. The VOC ground water plume in the eastern GSA is present in stream channel alluvium (Qal) at 3–9 m below ground surface; the plume is about 600-m long (**Figure 8-12**). Ground water in the alluvium flows down Corral Hollow Creek, east and northeast. Maximum fourth quarter 1998 total VOC concentrations were 11 ppb. The Qal is hydraulically connected to the Neroly Formation lower blue sandstone ($Tnbs_1$) unit.

The two VOC ground water plumes in the central GSA are present in terrace alluvium (Qt) and Neroly Formation upper blue sandstone ($Tnbs_2$), at a depth of 3–9 m below ground surface. These VOC plumes are about 200-m and 430-m long (**Figure 8-13**). Maximum fourth quarter 1998 total VOC concentrations were 540 ppb. Deeper regional ground water also contains total VOCs at a maximum fourth quarter 1998 concentration of 27 ppb. This ground water occurs at depths of 11–56 m below ground surface.

Details of current and planned environmental restoration activities at the GSA are summarized in the *Final Remedial Design* document (Ferry et al. 1998), submitted to the regulatory agencies in February 1998. The remedial design document includes the Contingency Plan and Compliance Monitoring Plan for the GSA operable unit (OU).

Building 834 Area

The Building 834 facility contains buildings where, in the past, TCE was used as a heat transfer fluid. Several large spills of TCE to the ground resulted in TCE contamination of a shallow perched water-bearing zone beneath the site. An isolated, perched water-bearing zone occurs in Pliocene nonmarine gravels (Tpsg) and occurs at a maximum depth of 9 m (30 ft) below the center of the complex. This perched zone crops out on all sides of the hill housing the Building 834 complex and is isolated from the underlying regional aquifer by over 60 m of vadose zone. The water-bearing zone contains maximum 1998 concentrations of TCE and 1,2-DCE of about 120,000 and 60,000 ppb, respectively. The resulting VOC plume is about 600-m long (**Figure 8-14**). Maximum

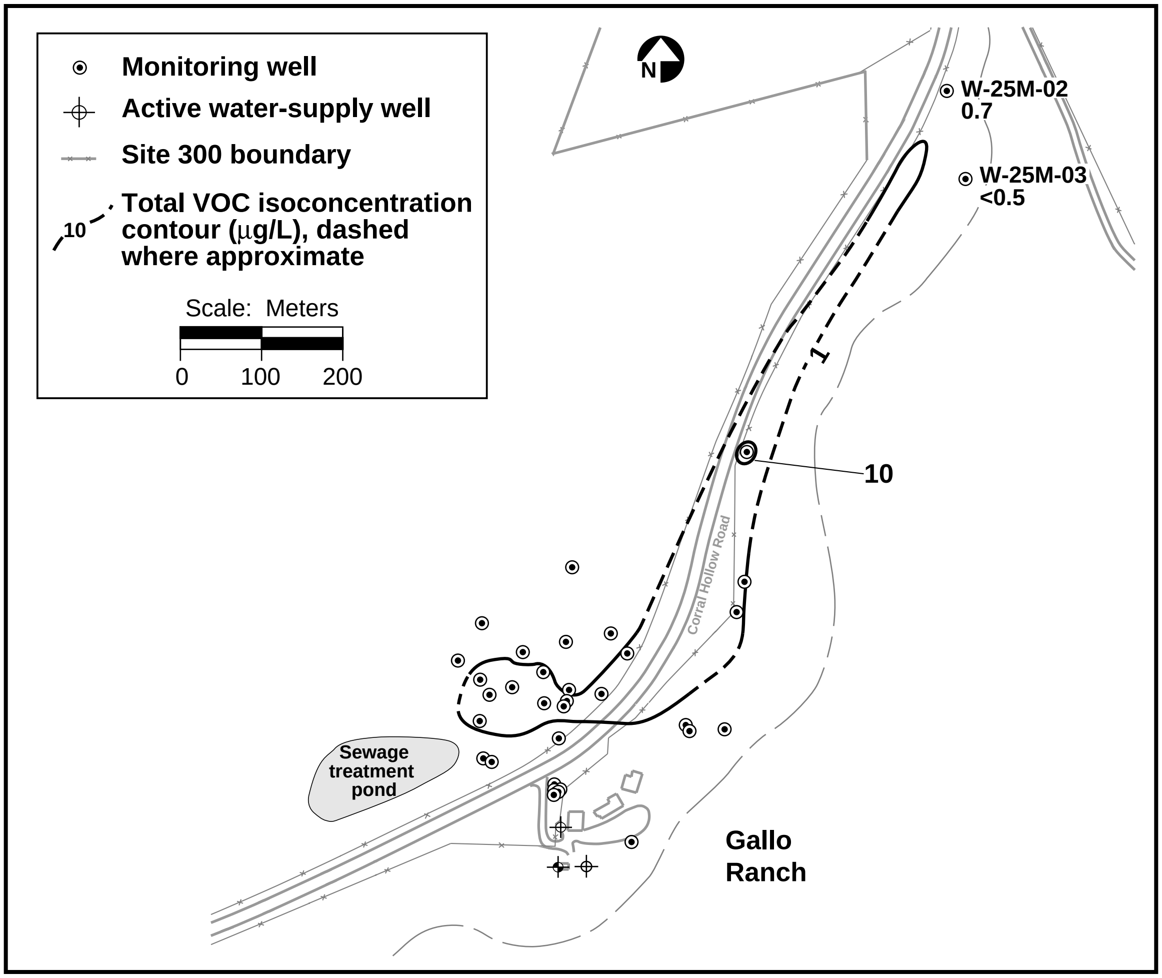


Figure 8-12. Total VOC concentrations in ground water in the eastern GSA and vicinity (second quarter, 1998). Monitor wells are completed in alluvial/shallow bedrock aquifer.

ground water nitrate concentrations are about 280 ppm. A silicate oil (tert-butyl orthosilicate) has been detected at maximum 1998 concentrations of 12,000 ppb. Currently, ground water and soil vapor extraction and treatment, using air-sparging and GAC, respectively, are in progress.

Explosives Process Area

The Explosives Process Area was established in the 1950s to chemically formulate, mechanically press, and machine high explosives (HE) compounds into detonation devices that are tested in explosives experiments in the East and West Firing Areas of Site 300. Process waste water from HE machining operations containing

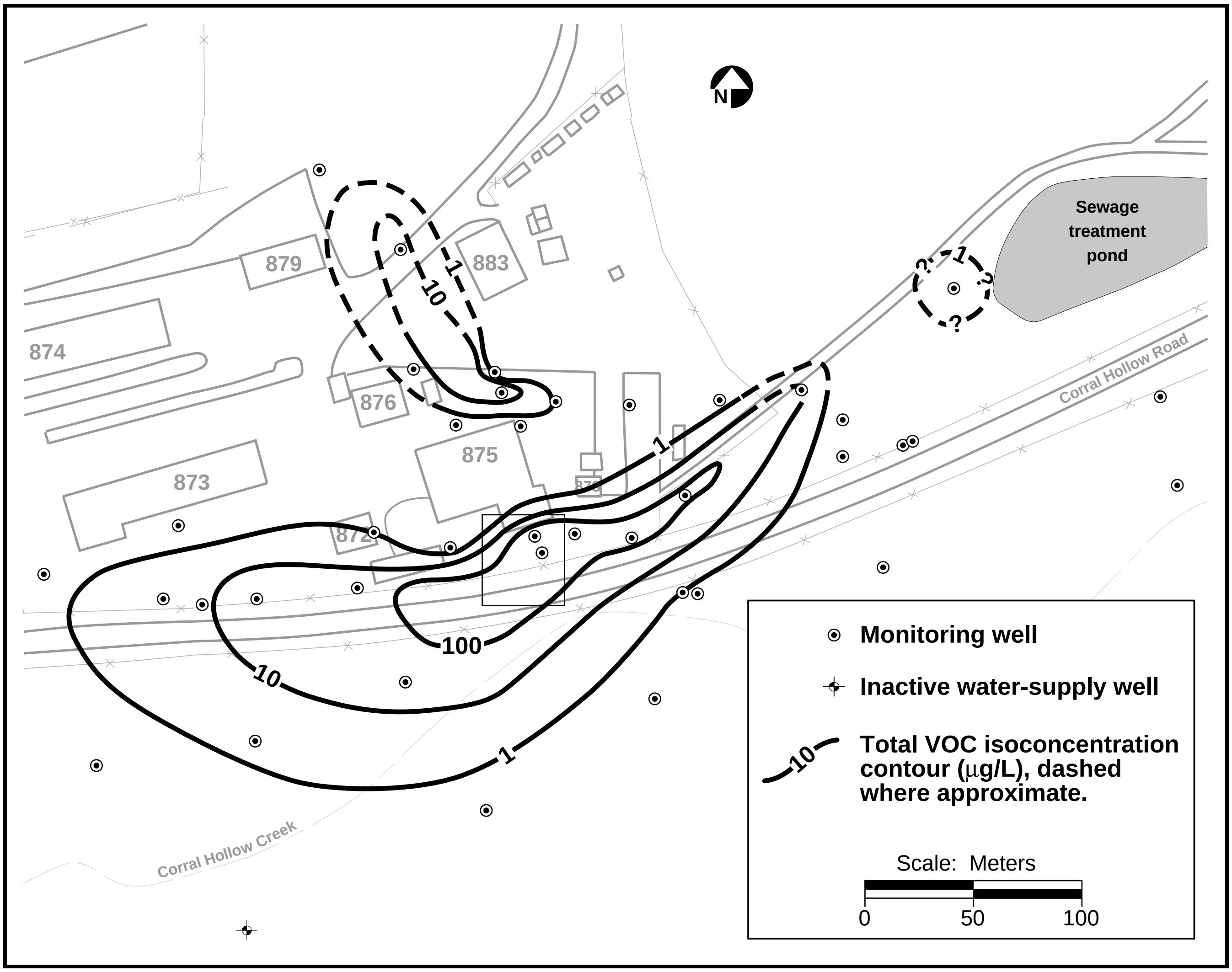


Figure 8-13. Total VOC concentrations in ground water in the central GSA (fourth quarter, 1998). Question marks indicate that the contour is unknown. Monitoring wells are completed in the Qt-Tnsc$_1$ hydrologic unit.

cyclotetramethyltetramine (HMX), hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), and nitrate was discharged to nine former unlined lagoons at concentrations high enough to impact ground water. A TCE hardstand located near the former Building 815 steam plant is considered to be the primary source of TCE ground water contamination. HMX and RDX are the most frequent and widespread HE compounds detected in soil and ground water. TCE, nitrates, and the RDX occur in two perched, water-bearing zones within the HE Process Area. These two water-bearing zones occur in Tps sediments and Tnbs$_2$ sandstone, respectively. Ground water occurs in these two zones at depths of 2–30 m, and 20–76 m, respectively. The VOC (principally TCE) plumes in Tps strata are

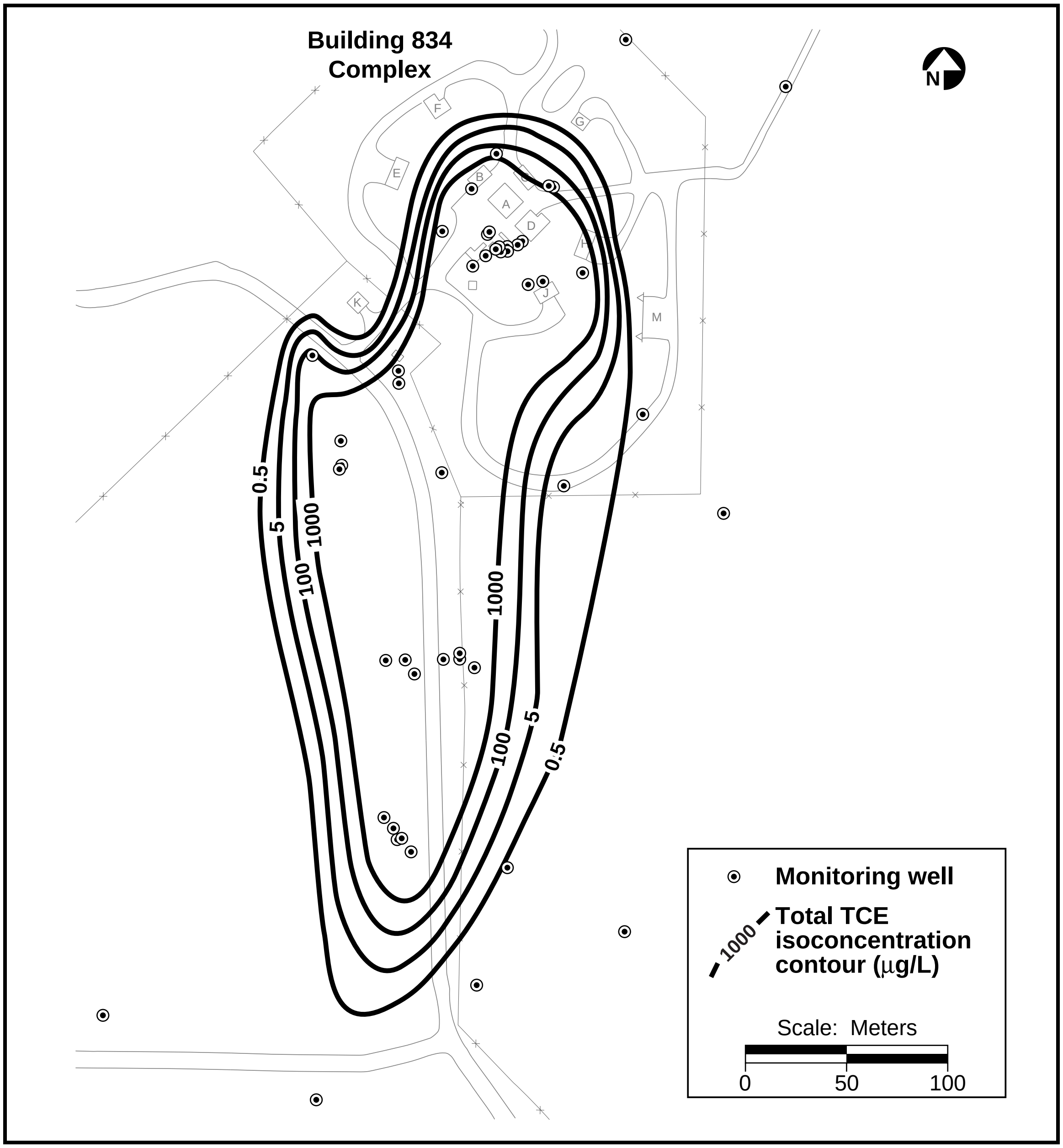


Figure 8-14. Distribution of trichloroethene in ground water in the Building 834 area (second quarter, 1998).

about 550-m and 200-m long (**Figure 8-15**). The RDX plume in $Tnbs_2$ strata is about 1200-m long. The perchlorate plume in $Tnbs_2$ strata is 4900-m long. Current 1998 maximum concentrations of 1,1-DCE, 1,2-DCE, and TCE are 4.7, 3, and 330 ppb, respectively. Maximum concentrations of RDX, HMX, nitrate, and perchlorate are 87, 67, 102 ppm, and 50 ppb, respectively. A small plume of TCE (maximum 1998

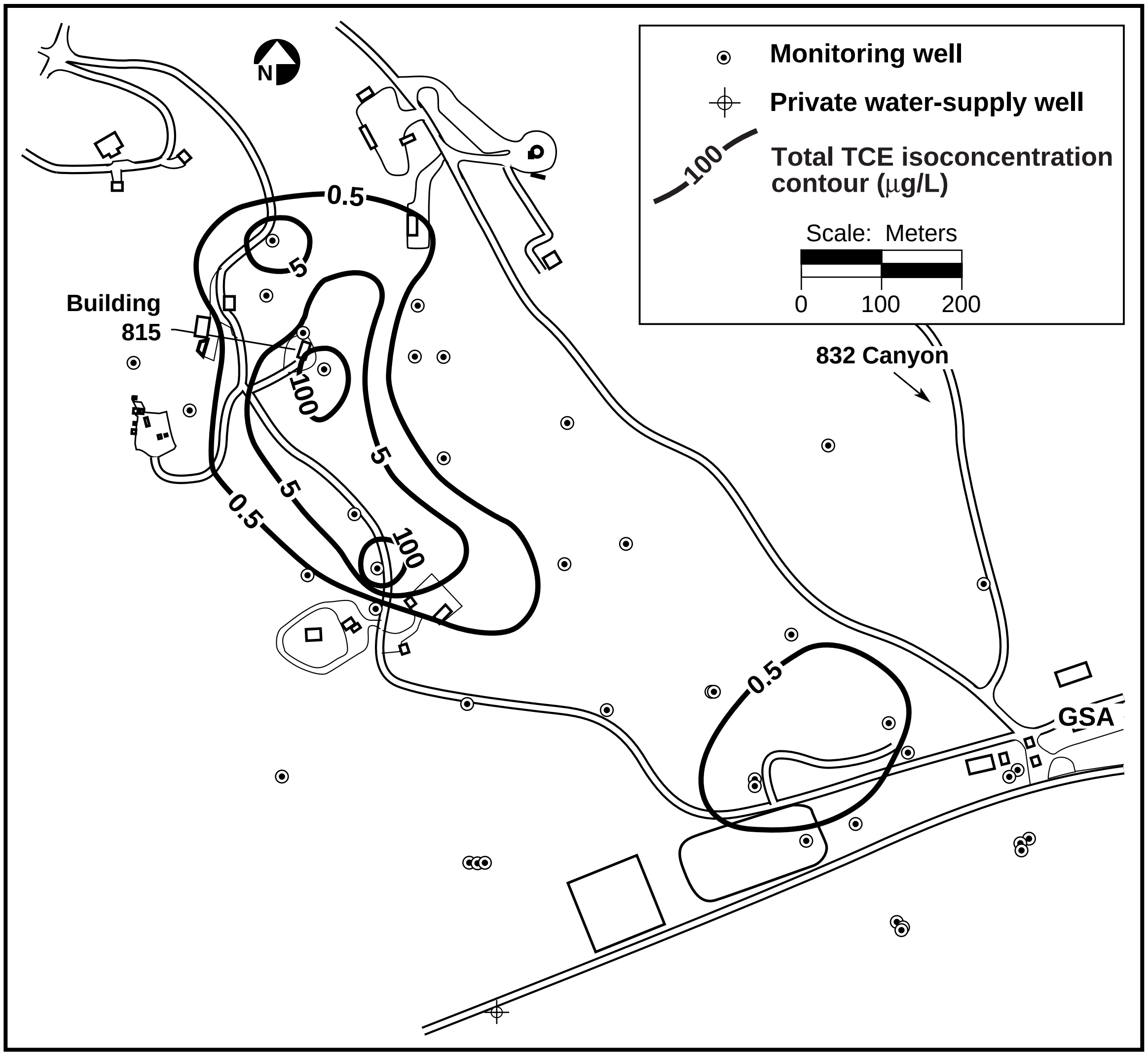


Figure 8-15. Distribution of trichloroethene in the Explosives Process area (second quarter, 1998). Monitoring wells are completed in the Tps aquifer.

concentration of 310 ppb) also occurs in a local perched water-bearing zone that occurs in $Tnsc_1$ strata at a depth of 24–30 m below the HE burn pits; this plume is less than 5-m long. These burn pits were closed and capped under RCRA in 1998.

East and West Firing Areas

Explosives experiments conducted at outdoor firing tables in this area have generated wastes that were disposed at several unlined landfills in the past. Tritium has been released to ground water from landfill Pits 3 and 5 and the Building 850 firing table (**Figure 8-16**). Depleted uranium has been released to ground water from landfill Pits 5

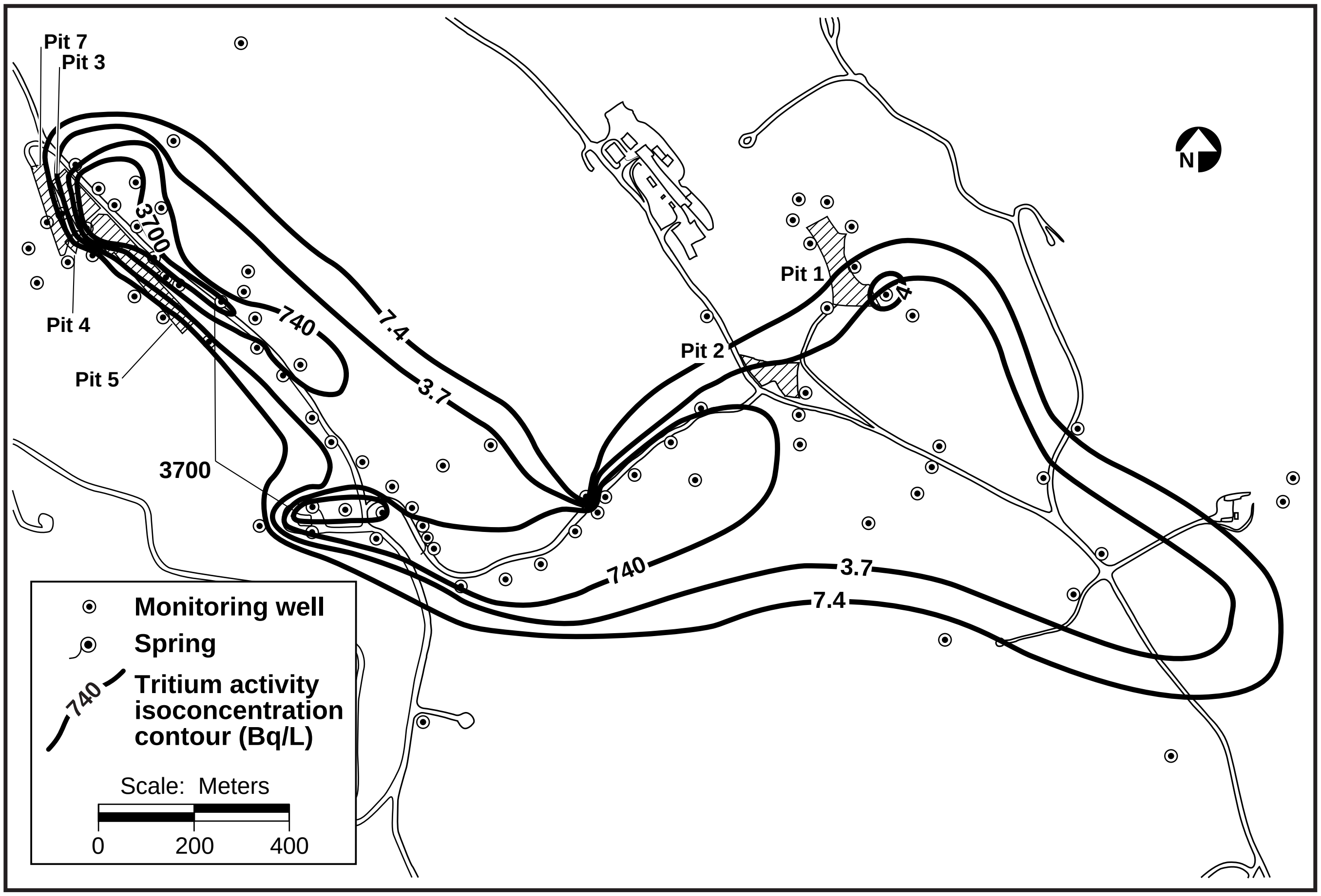


Figure 8-16. Distribution of tritium in ground water in the first water-bearing zone in the Building 850/Pit 3 and 5 area (second quarter, 1998).

and 7 and the Building 850 firing table. The resulting plumes occur in a perched water-bearing zone within Qal and $Tnbs_1$. The water-bearing zone occurs at depths of 5–20 m below surface. There are two overlapping plumes of tritium in ground water at maximum 1998 activities of about 2.7 million pCi/L. The total length of the commingling tritium plumes is about 3000 m. The perched water-bearing zone is connected to the regional $Tnbs_1$ aquifer at the Elk Ravine Fault. Maximum tritium activities in this aquifer are about 5000 pCi/L. There are two smaller plumes of depleted uranium (uranium-238) in ground water, with maximum 1998 activities of less than 100 pCi/L. The depleted uranium is confined to the perched water-bearing zone; the lengths of these two uranium plumes are 370 m and 500 m. Computer modeling of the transport and fate of the tritium indicates that by the time the tritium and uranium in ground water reach the Site 300 boundary, these radionuclides will exist at near-background activities.

The annual assessment of tritium inventories in ground water that began in 1985 continued in 1998. The analysis, which included evaluation of the inventories of tritium in the vadose zone available for leaching to ground water, indicated that the two tritium plumes emanating from the landfill are stable with regard to measured tritium concentrations and area impacted, while the Building 850 plume is decreasing at the radioactive decay rate. Although tritium continues to leach into ground water from vadose zone sources, the long-term trend in total ground water tritium activity is one of decreasing activity at approximately the radioactive decay rate of tritium.

In 1998, LLNL submitted to the regulatory agencies the *Ground Water Tritium Plume Characterization Summary Report for the Building 850/Pits 3 and 5 Operable Unit, Lawrence Livermore National Laboratory Site 300* on October 30, 1998 (Ziagos and Reber-Cox 1998b). The report documents our assessment of semiannual ground water tritium inventories, vadose-zone tritium inventory, and an update on hydrogeology in the operating unit.

Several other contaminants in ground water are being investigated by LLNL at the East and West Firing Areas. Nitrates and perchlorates in the Building 850 / Pit 3 and 5 areas occur at maximum 1998 concentrations of less than 100 ppm and 8.7 ppb, respectively. Trace amounts of TCE (less than 3 ppb) are also present in ground water near Pit 5. TCE also occurs in a small ground water plume monitored by two wells at the Building 801 firing table. Freon-113 at concentrations significantly below the California maximum contaminant level of 1.2 ppm is present near Pit 1 and is the result of spills at Building 865 (Advanced Test Accelerator).

Depleted uranium isotopic signatures have been detected in ground water samples from wells adjacent to the Building 851 firing table, indicating that some depleted uranium is reaching ground water. No monitor wells have yet been drilled at Building 812, a firing table where depleted uranium and thorium were used in explosives experiments. However, samples from an adjacent perennial spring indicate depleted uranium signatures.

Remedial investigations for the Building 812 and 865 areas are planned for the near future.

Building 854 Study Area

Trichloroethene in the ground water was previously found to arise principally from leaks in the former overhead TCE brine system at Buildings 854E and 854F. Trichloroethene, nitrates, and perchlorates occur in ground water in the Building 854 area in Neroly Formation $Tnbs_1$ strata at maximum 1998 concentrations of 410, 180, and 7.4 ppb, respectively. The affected aquifer occurs at depths of 9–50 m below ground surface. The TCE plume is about 970-m long (**Figure 8-17**).

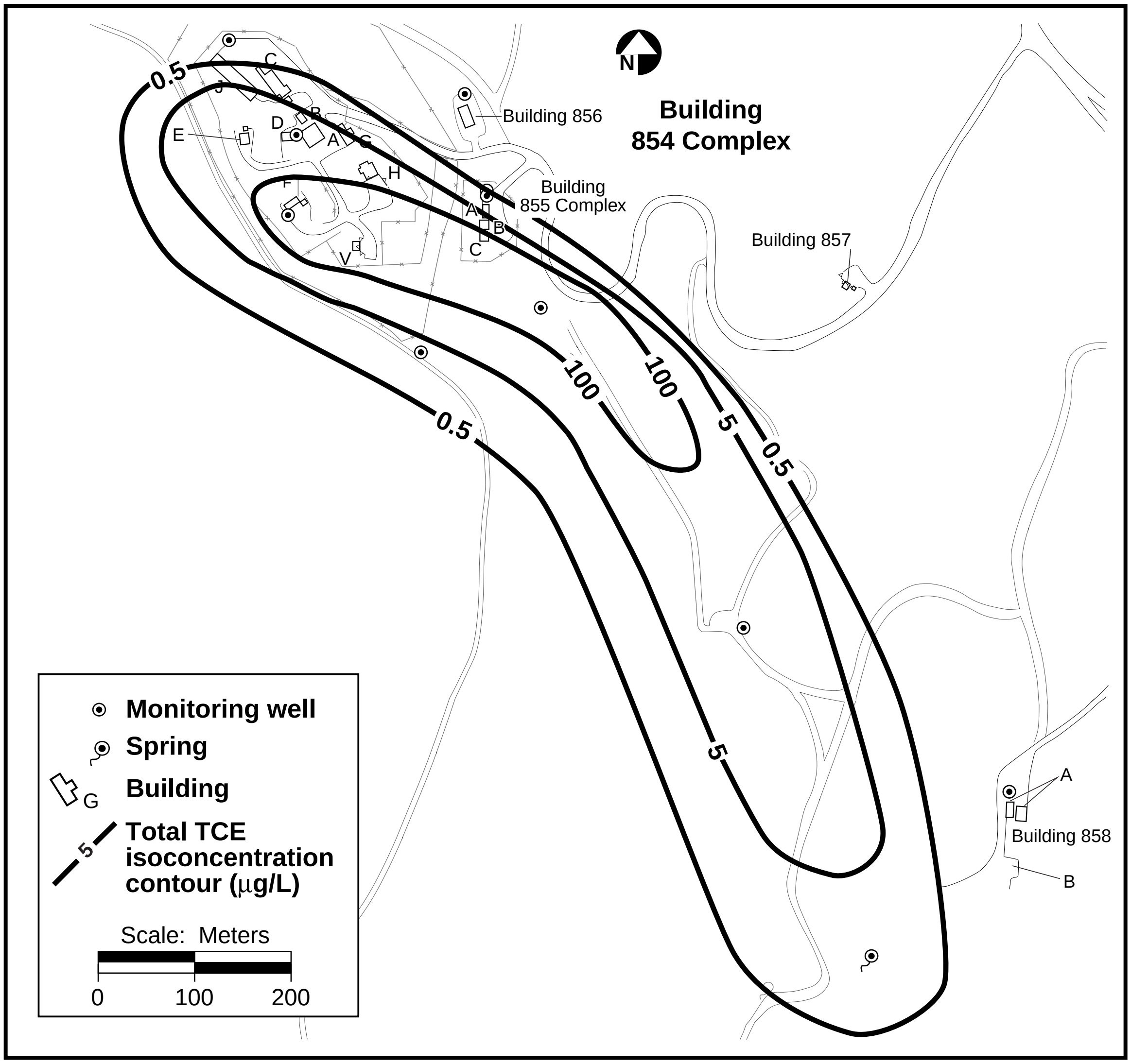


Figure 8-17. Distribution of trichloroethene in ground water in the Building 854 area (second quarter, 1998).

During 1998, LLNL continued to define the extent of TCE in soil, soil vapor, and ground water. Three new monitor wells were installed, and colloidal borescope surveys were performed. The colloidal borescope is an innovative downhole instrument that tracks natural colloids in the wellbore to measure ground water flow direction and seepage velocity. On April 1, 1998, LLNL submitted the *Characterization Summary Report for the Building 854 Operable Unit* (Ziagos and Reber-Cox 1998c) to the regulatory agencies. On May 28, 1998, LLNL submitted to the regulatory agencies a letter detailing the CERCLA pathway for the operable unit (U.S. Department of Energy 1998e). LLNL plans to begin installation and operation of a solar-powered potable treatment unit at Building 854 to treat extracted ground water containing VOCs in 1999.

Pit 6 Area

A small ground water TCE plume in a perched terrace alluvium (Qt) water-bearing zone discharges to the surface at small springs at the southeastern edge of the Pit 6 area. The perched water-bearing zone occurs at depths of 0–11 m below ground surface. The source of the TCE plume is the southeast corner of the Pit 6 landfill. The TCE plume is about 200-m long (**Figure 8-18**). Because of natural volatilization of affected ground water at the springs, concentrations of VOCs in the plume have declined by more than tenfold since 1992. Current maximum TCE concentrations are about 16 ppb. Tritium (at maximum activities of 91 Bq/L), nitrate (at maximum concentrations of 228 ppm), and perchlorate (at maximum concentrations of 65.2 ppb) also occur in the perched water-bearing zone. Tritium also occurs in the $Tnbs_1$ regional aquifer which occurs at depths of 30–53 m below ground surface, at concentrations of up to 37 Bq/L. The lengths of the tritium and perchlorate plumes are 200 and 400 m, respectively.

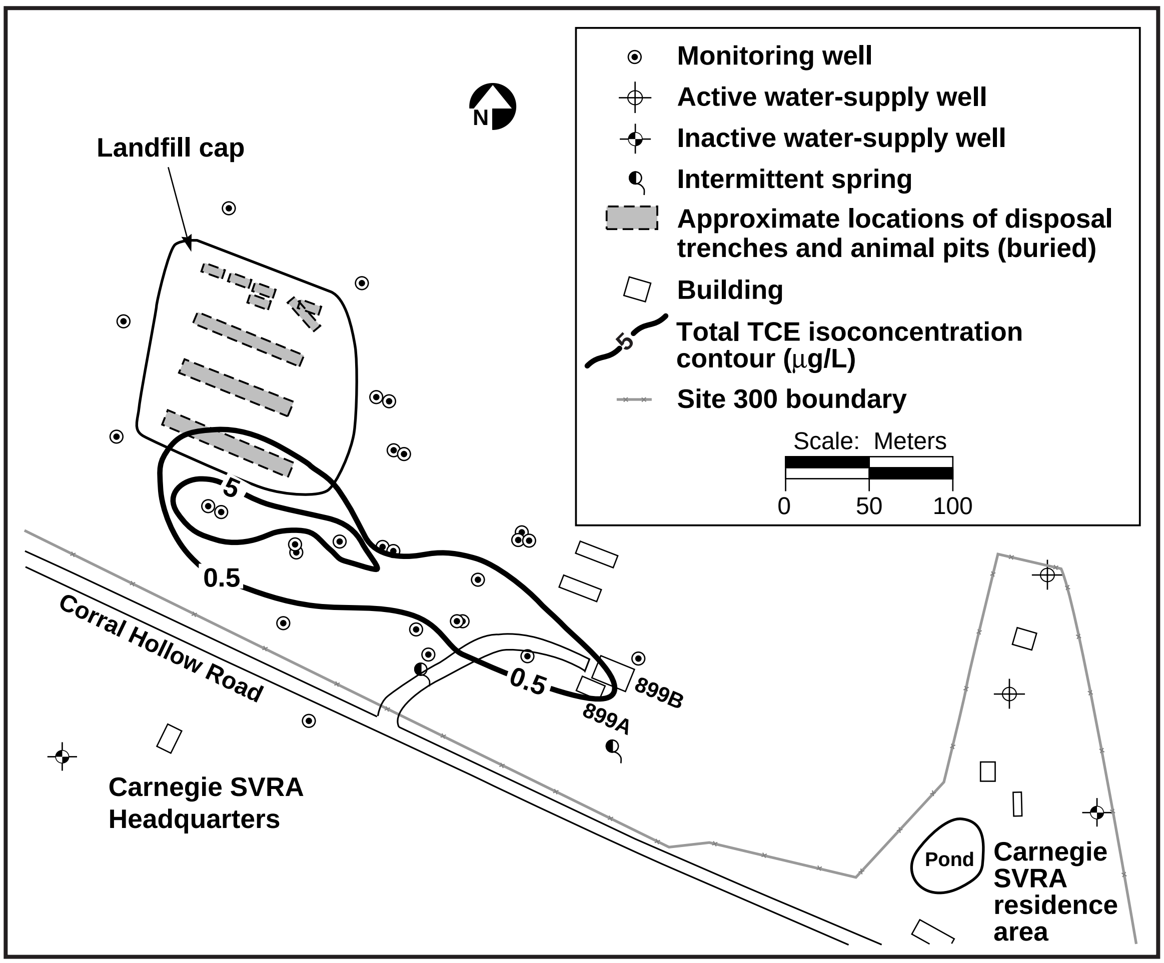


Figure 8-18. Distribution of trichloroethene in ground water in the Pit 6 area (second quarter, 1998).

During 1997, a 2.4-acre engineered cap was constructed over the landfill as a CERCLA nontime-critical removal action. During 1998, the Post-Closure Plan (Ferry et al. 1998) for the Pit 6 cap was submitted to the regulatory agencies. Additionally, a multi-well observation pump test was performed in the area of maximum ground water TCE concentration to determine hydraulic parameters and the effective radius of pumping. Volume and mass of ground water extracted and TCE treated, respectively, during this test are tabulated in **Table 8-5**.

Building 832 Canyon Study Area

At the Building 832 Canyon area (Buildings 830 and 832), solvents were released from weapons component test cells in the past. TCE and nitrate occur in ground water in Neroly Formation $Tnsc_1$ silty-claystone strata 15–25 m beneath the Building 832 Canyon Study Area at maximum 1998 concentrations of 7900 ppb and 140 ppm, respectively. The TCE plume emanates from both the Building 830 and 832 areas and is about 1300-m long (**Figure 8-19**). Perchlorate has also been detected at maximum concentrations of 22 mg/L. Well drilling during 1998 indicated that the TCE contaminant plume and the nitrate in ground water, both emanating from the Building 832 complex, are likely merging with the TCE and nitrate in ground water coming from Building 830, giving rise to the TCE plume. Perchlorate has also been detected in ground water samples from 18 monitor wells in the area.

In 1998, LLNL completed 12 wells in the Building 832 complex, near the suspected test cell release sites, for TCE extraction and monitoring and began construction of the treatment system. LLNL plans to use green technologies to treat ground water in the Building 832 Canyon area. A DOE Technology Deployment Initiative (TDI) using iron filings as a treatment system for TCE is in the design and testing phase.

Environmental Remediation at Site 300

Dedicated ground water and soil vapor extraction and treatment facilities exist at the eastern GSA, central GSA, and Building 834 areas. The central GSA treatment facility and the eastern GSA treatment facility discharge to surface drainage courses. Treated water from a pump test at Pit 6 was also discharged to a drainage channel just south of the pit. **Table 8-5** summarizes calendar year 1998 and cumulative totals of volumes and masses of contaminants removed from ground water and soil vapor at the Site 300. Also in 1998, treatment facility construction, design, and treatability testing activities began for the Explosives Process and Building 832 areas.

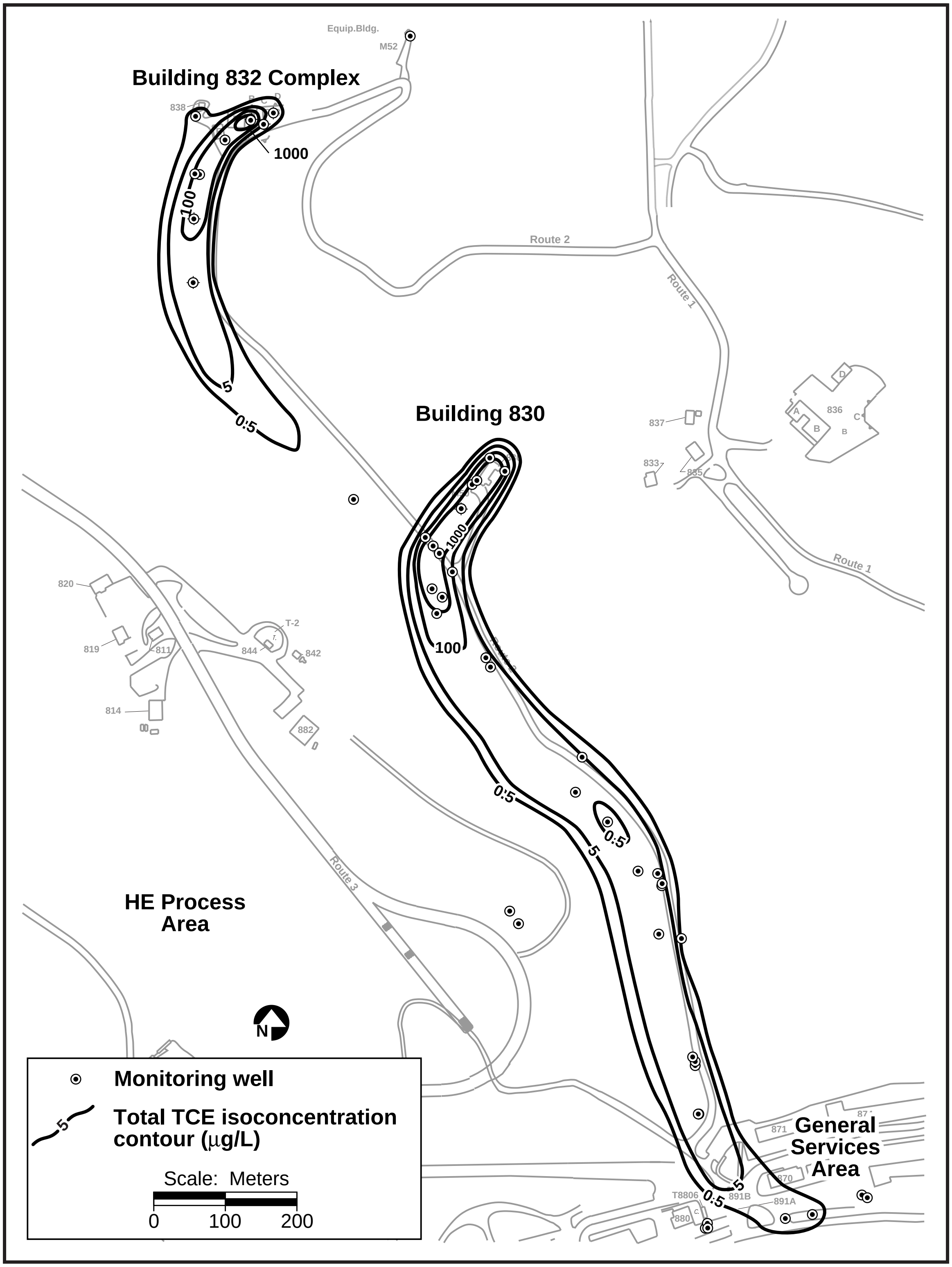


Figure 8-19. Distribution of trichloroethene in the combined Qal, $Tnbs_2$, and $Tnsc_1$ aquifers in the Building 832 Canyon (second quarter, 1998).

Table 8-5. Volatile organic compounds (VOCs) removed from ground water and soil vapor at Site 300.

Treatment area	Startup date	1998		Cumulative total	
		Water treated (ML)[a]	VOCs removed (kg)	Water treated (ML)[a]	VOCs removed (kg)
General Services Area					
Eastern GWTF[b]	6/91	69.1	0.34	478	5.6
Central GWTF	4/93	1.6	0.93	4.8	6.5
Building 834	10/95	0.164	3.66	0.413	19.2
Pit 6	11/98	0.268	0.0014	0.268	0.0014
		Soil vapor treated (m^3)	VOCs removed (kg)	Soil vapor treated (m^3)	VOCs removed (kg)
General Services Area					
Central	1994	557,530	9.16	1,003,665	39.46
Building 834	1998	49,191	7.27	49,191	7.27

a ML = 1 million liters.

b GWTF = Ground water treatment facility.

General Services Area

The Remedial Design Document for the GSA Operable Units was submitted to the regulatory agencies on February 16, 1998. The soil vapor extraction and treatment system in the central GSA dry-well source area was consistently operated and maintained to reduce VOC concentrations in soil vapors, remediate dense nonaqueous-phase liquids in the soil, and mitigate the VOC inhalation risk inside Building 875. The ground water extraction and treatment systems in the central and eastern GSA area were consistently operated and maintained to reduce VOC concentrations in the ground water to drinking water maximum contaminant levels (MCLs), prevent further migration of the contaminant plume, and dewater the shallow water-bearing zone in the Building 875 dry-well area to enhance soil vapor extraction. Wells W-7Q, W-7R, W-7S, and W-7T were installed within the central GSA as monitor wells. These wells are being considered as possible extraction wells for the expansion of the ground water treatment facility. Based on the NPDES permit 5-year review, sampling requirements were reduced at the eastern GSA groundwater treatment facility.

The eastern GSA treatment facility employs granular activated carbon (GAC) canisters to remove VOCs from extracted ground water. Extracted central GSA ground water is run through an air-sparging PTU to remove VOCs. Extracted soil vapor at the central GSA is run through GAC canisters to remove VOCs.

Ground water treated at the eastern GSA ground water treatment facility was discharged off site to the Corral Hollow Creek, in accordance with NPDES Permit No. CA0082651. **Table 8-5** shows the amount of the water treated and VOCs removed at the eastern GSA. The length of the eastern GSA TCE plume with concentrations over the cleanup standard of 5 ppb (MCL) has been reduced by over 1400 m. The off-site portion of the plume now extends only 30 m beyond the site boundary. TCE concentrations in influent from the eastern GSA ground water treatment system were reduced from 64 ppb in January 1992 to 11 ppb in November, 1998. Only one off-site well in the eastern GSA has a TCE concentration over the cleanup standard of 5 ppb (MCL). LLNL estimates that seven more years of ground water extraction and treatment will be required to achieve and maintain ground water VOC concentrations below MCLs at the eastern GSA.

At the central GSA treated ground water was collected and batch-discharged in a remote Site 300 canyon, in accordance with the substantive requirement for wastewater discharge. TCE concentrations in central GSA ground water treatment system (GWTS) influent have been reduced from 9400 ppb in 1993 to 410 ppb in 1998.

Following dewatering of bedrock through ground water extraction, soil vapor extraction and treatment of VOCs began in 1994. **Table 8-5** shows the amounts of soil vapor treated and VOCs removed at the central GSA. From 1994 through the end of 1998, VOC concentrations in the central GSA soil vapor extraction influent stream were reduced from 450 ppmv to 2.3 ppmv. VOC concentrations in individual central GSA soil vapor extraction wells have been significantly reduced.

The central GSA ground water treatment system is operating under substantive requirements for wastewater discharge issued by the Central Valley RWQCB. The central GSA treatment facility discharges to bedrock in the eastern GSA canyon, where the water percolates into the ground. The eastern GSA ground water treatment system operates under NPDES Permit No. CA0082651, issued by the Central Valley RWQCB for discharges into Corral Hollow Creek. The system operated under WDR91-052 until December 5, 1997, when WDR 97-242 was issued. Permit requirements for the central and eastern GSA ground water treatment system are listed in **Table 8-6**. Both the central and eastern GSA treatment systems operated in compliance with regulatory requirements during 1998. LLNL submitted quarterly reports for the GSA treatment systems to the California EPA and the RWQCB in accordance with the National Pollutant Discharge Elimination System Order No. 97-242 for the eastern GSA and the Substantive Requirements for Waste Discharge for the Central GSA (Lamarre 1998a, b, c, and d).

Table 8-6. General Services Area ground water treatment system surface discharge permit requirements.

Parameter	Treatment facility	
	Central General Services Area	**Eastern General Services Area**
VOCs	Halogenated and aromatic VOCs	Halogenated VOCs
Maximum daily	5.0 µg/L	5.0 µg/L
Monthly median	0.5 µg/L	0.5 µg/L
Dissolved oxygen	Discharges shall not cause the concentrations of dissolved oxygen in the surface water drainage course to fall below 5.0 mg/L.	Discharges shall not cause the concentrations of dissolved oxygen in the surface water drainage course to fall below 5.0 mg/L.
pH (pH units)	Between 6.5 and 8.5, no receiving water alteration greater than ±0.5 units.	Between 6.5 and 8.5, no receiving water alteration greater than ±0.5 units.
Temperature	No alteration of ambient receiving water conditions more than 3°C.	No alteration of ambient receiving water conditions more than 3°C.
Place of discharge	To ground water during dry weather and to surface water drainage course in eastern GSA canyon during wet weather.	Corral Hollow Creek.
Flow rate	272,500 L (30-day average daily dry weather maximum discharge limit).	272,500 L per day
Mineralization	Mineralization must be controlled to no more than a reasonable increment.	Mineralization must be controlled to no more than a reasonable increment.
Methods and detection limits for VOCs	EPA Method 601—detection limit of 0.5 µg/L. EPA Method 602—method detection limit of 0.3 µg/L.	EPA Method 601—detection limit of 0.5 µg/L.

Building 834 Complex

In January 1998, the GWTS was returned to full-scale operation after running intermittently for the second half of 1997. Work commenced to automate the system to allow for 24-hour operation in future years. Most importantly, a soil vapor extraction system was activated in July of 1998 that helped to triple mass removal at the site by extracting an additional 7 kg of VOCs from the subsurface over the course of the year. In order to increase the effectiveness of the treatment system even more, a work plan was put in place to expand the extraction wellfield by 1999 by converting a number of monitoring wells into combined ground water and soil vapor extraction wells. An analysis of historic site data with state-of-the-art computational tools was extremely valuable in visualizing the behavior of TCE and its derivatives at the site. Animated plume history analyses for TCE and its biotransformation product *cis*-1,2-dichloroethylene (*cis*-DCE) revealed that during 1989 to 1997: (1) the contour of the TCE plume did not expand, (2) concentrations of TCE decreased significantly in the release area, (3) biotransformation of TCE to *cis*-DCE was an important mechanism contributing to natural attenuation of TCE at the site, and (4) this biotransformation process depended on the presence of silicon oil in the plume. In laboratory experiments, staff from LLNL and the Oregon State University were able to reproduce and quantify some of the contaminant transformation processes occurring in the field. Two forthcoming peer-reviewed publications report on the novel microbial process that exploits alkoxysilane lubricants as drivers for TCE bioattenuation.

Table 8-5 shows amounts of water treated and VOCs removed at Building 834. Quarterly reports for the Building 834 treatment facility were submitted to the California EPA and the RWQCB in accordance with the Substantive Requirements for Waste Discharge (Lamarre 1998e, f, g, and h). Because treated ground water is discharged to misters and is not discharged to the ground, there are no treatment system surface discharge permit requirements for Building 834.

Explosives Process Area

The final *Action Memorandum for the Building 815 Operable Unit Removal Action at Lawrence Livermore National Laboratory Site 300* (Jakub 1998) was submitted to the regulatory agencies on August 17, 1998. This report describes the main components of the removal action, estimates removal action costs, and addresses all verbal and written comments submitted by the community during the public workshop. The *Building 815 Removal Action Design Workplan for the High Explosives Process Area at Lawrence Livermore National Laboratory Site 300* (Ziagos and Reber-Cox 1998a) was submitted to the regulatory agencies on November 15, 1998. This report describes the removal action in more detail and provides a contingency plan to address foreseeable problems that may arise during this removal action.

During 1998, LLNL capped the high explosives burn pits with an impermeable cap. A construction quality assurance report for the cap (Golder Construction Services 1998) was submitted to the regulatory agencies on September 9, 1998.

Two hydraulic tests were conducted during 1998 on wells located near the leading edge of the TCE plume at the Site 300 boundary to help design the extraction wellfield for the removal action. The objective of these tests was to determine long-term yield and hydraulic capture area. The hydraulic test results along with ground water modeling results were used to help design the removal action and prepare the removal action design work plan. The removal action consists of pumping and treating from two existing ground water monitoring wells, although additional wells may be added depending on the performance from these two wells. Ground water treatment will consist of removing TCE with aqueous phase granular activated carbon.

Treatability testing began in 1998 to evaluate cost-effective ground water treatment technologies for the second phase of ground water cleanup. Most of the technologies being considered are dual-phase removal and destruction technologies to remediate nitrates and HE compounds, including perchlorate. These technologies use granular activated carbon, ion-exchange, or electro-migration for contaminant removal and ex-situ bioremediation for contaminant destruction. Phytoremediation, using indigenous grasses, is also being evaluated for treating nitrate-bearing ground water.

Pit 6 Landfill Area

During 1998, LLNL conducted a pump test at Pit 6, to determine hydraulic parameters of aquifer materials and to define the radial influence of pumping wells located in the center of mass of the ground water TCE plume. The test was also successful in reducing local ground water TCE concentrations to just slightly above detection limits. The volume of water extracted and TCE mass removed during the test is tabulated in **Table 8-5**. The test ran from October 11 to December 3, 1998.

Building 832 Canyon

The maximum concentration of TCE reported in ground water samples collected from wells in the Building 832 Canyon area was 7 ppm.

The first step toward TCE mass removal in the operable unit was completed with the submittal and acceptance of the Building 832 Canyon Operable Unit Treatability Study Workplan in November 1997. This workplan set forth plans for ground water and soil vapor TCE extraction and treatment in 1998 and beyond, using portable treatment units, solar-powered water activated-carbon treatment units, and soil vapor extraction systems. Also under consideration is the use of a subsurface iron filings permeable reactive treatment wall in the lower canyon area to intercept the TCE-laden ground water, destroy the TCE and degradation products, and help control the migration of the TCE plume off site.

Community Relations

LLNL met three times with members of Tri-Valley Citizens Against a Radioactive Environment and their technical advisor as part of the activities funded by an EPA Technical Assistance Grant. A public workshop for the Pit 6 removal action capping was held on January 15, 1997.